

Factors affecting small-sided game demands among high-level junior rugby league players

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Declaration

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Abstract

Small-sided games (SSGs) are commonly incorporated into the conditioning programmes of rugby league (RL) players. However, although several studies have examined the physiological, perceptual, movement and skill demands of SSGs, the majority of research in this area has focused on these responses in soccer players. Therefore, the purpose of this programme of research was to examine the effects of altering selected variables (player number, playing area size, the role of the player and the role of the coach) on the physiological and technical demands imposed on junior, high-level RL players during SSGs. In addition, SSG responses were investigated in different junior age groups to determine if playing age has an effect on SSG demands. Finally, given the role of SSGs as a conditioning tool, the consistency of the exercise intensities generated was assessed over repeated trials.

Chapter 3 investigated the influence of player number and playing area size on the heart rate (HR) responses elicited by junior male RL players during SSGs. Twenty-two players from a professional club (mean age: 14.5 ± 1.5 yr; stature: 172.5 ± 11.4 cm; body mass: 67.8 ± 15.1 kg; $\dot{V}O_{2\text{ peak}}$: 53.3 ± 5.6 ml·kg⁻¹·min⁻¹; HRmax: 198 ± 7.8 b·min⁻¹) participated in two repeated trials of six four-minute conditioned SSGs over a two-week period. The SSGs varied by playing area size; 15x25 m, 20x30 m, and 25x35 m, and player number; 4v4 and 6v6. Analysis revealed non-significant ($P>0.05$) effects of trials and playing area size on HRs, but a significant effect of player number in the U16 age group only ($P<0.001$), with HRs being higher in the 4v4 (90.6% HRmax) than the 6v6 SSGs (86.2% HRmax). The HR responses were found to be repeatable in all SSG conditions (within $\pm 1.9\%$ HRmax) apart from the small 6v6 condition in the older players.

Chapter 4 investigated the HR responses and incidence of specific game actions during attacking and defending play in SSGs, with and without coach encouragement. Seventeen boys from a professional club (mean age: 13.4 ± 1.1 yr; stature: 168 ± 11.8 cm; body mass: 61.5 ± 14.9 kg; $\dot{V}O_{2\text{ peak}}$: 55.0 ± 5.6 ml·kg⁻¹·min⁻¹; HRmax: 202 ± 6.5 b·min⁻¹) participated in two repeated trials of

four, four-minute conditioned SSGs over a two-week period. It was observed that attacking play elicited a greater amount of time above 90% HRmax than defending (62.0 ± 31.5 versus $48.4 \pm 31.3\%$ of total time). Compared to the older junior players (U15), the younger junior players (U13) elicited a greater average SSG intensity ($90.5 \pm 1.7\%$ versus $87.9 \pm 0.6\%$ HRmax) and spent a greater amount of time above 90% HRmax ($68.6 \pm 22.5\%$ versus $43.3 \pm 34.6\%$ of total time). Moreover, compared to the U15 players, the U13 players completed a greater volume of passes (20.8 ± 2.9 versus 15.5 ± 2.6), successful passes (21.3 ± 0.0 versus 17.4 ± 3.1), pass plays (6.6 ± 1.4 versus 3.0 ± 0.5) and tries (2.5 ± 1.1 versus 0.6 ± 0.3), but a lower volume of attacking runs (25.9 ± 1.3 versus 32.3 ± 0.2), dummy runs (10.6 ± 1.8 versus 18.9 ± 1.8), touches (30.0 ± 35.0 versus 35.8 ± 6.3), successful touches (30.5 ± 0.5 versus 42.1 ± 1.1) and completed sets (1.6 ± 0.0 versus 3.5 ± 0.6). The addition of coach encouragement had no effect on the HR responses or volume of game actions conducted. The SSGs demonstrated large trial-to-trial variability in the game actions and average and peak HR intensities (bias of $3.7 \pm$ and $\pm 4\%$ HRmax) and percentage of time in HR Zones (bias of $\pm 25\%$ percentage of time), indicative of poor reliability.

The findings from this research demonstrate that SSGs specific to RL can generate HR responses suitable for aerobic conditioning that, whilst unaffected by the size of the area used, are sensitive to the player number, player role and age. Moreover, coach encouragement may not affect SSG demands when players are habituated to SSG conditioning. Furthermore, manipulating SSG rules can adversely affect the reproducibility of HR responses.

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Abbreviations

ACSM	American College of Sports Medicine
ANOVA	Analysis of variance
$a-\dot{V}O_2$	Arterial-mixed venous oxygen difference
CV	Coefficient of variation
GPS	Global positioning system
HIT	High-intensity interval training
HR	Heart rate
HRpeak	Peak heart rate
%HRmax	Maximal percentage of heart rate
%HRrecovery	Percentage of heart rate recovery score
%HRreserve	Percentage difference between resting and maximal heart rate
LoA	Limits of agreement
LT	Lactate threshold
MSFT	Multi-stage fitness test
NRL	Australian National Rugby League
PPO	Peak power output
PTB	Play-the-ball
RL	Rugby league
RPE	Rating of perceived exertion
RSA	Repeated sprint ability
SD	Standard deviation
SSG	Small-sided game
SL	English Super League
SV	Stroke volume
TGfU	Teaching games for understanding
TMA	Time-motion analysis
UKCC	United Kingdom Coaching Certificate
$\dot{V}O_2$	Oxygen uptake
$\dot{V}O_{2peak}$	Peak oxygen uptake

Abbreviations continued

$\dot{V}O_{2\max}$	Maximal oxygen uptake
$v\dot{V}O_{2\max}$	Velocity of maximal oxygen uptake
WRR	Work to rest ratio
\dot{Q}	Cardiac output

Chapter 1.0 Introduction

1.1 The game of rugby league

Rugby league (RL) is a contact team sport that is intermittent in nature, with periods of high intensity activity interspersed with periods of low intensity activity (Gabbett et al., 2008a). Games are divided into two halves of 30 and 40 minutes for junior and senior players, respectively, and involve sequences of six consecutive plays (a set) in which the attacking team pass the ball backwards, and/or kick and run with it in an attempt to reach the opposition's try line and score by placing the ball over the line. Progress can be impeded by a player with the ball being tackled, following which, play recommences by the tackled player passing the ball uncontested between his/her feet to another attacking player ('play-the-ball', PTB) (Meir et al., 2001a). Following each tackle the defence must retreat 10 metres before they are allowed to return to play following the PTB. The team in possession is permitted six tackles before play is turned over unless an infringement has been made or a try or field goal has been scored (Gabbett et al., 2008a). Rugby league players are grouped into nine positional roles (prop, second row, loose forward, scrum half, hooker, stand off, centre, winger and full back) and are more generally classified as forwards and backs, notably players who are present within the scrum restart and those who are absent from the scrum, respectively (Meir et al., 2001a; Gabbett, 2002a). In addition, researchers have utilised more specific positional sub-groups (Meir et al., 2001b; Gabbett, 2005c; 2005e, 2006c, Gabbett et al., 2008a); commonly props, hookers and halves (scrum halves and stand offs), back row (second row and loose forwards) and outside backs (centres, wings and full backs).

1.2 Conditioning of rugby league players

As RL is a high-intensity, intermittent sport that places considerable demands on both aerobic and anaerobic metabolic systems during competition, it has attracted particular research on the efficacy of various training methods in the preparation of its players. Traditional aerobic conditioning methods, such as continuous steady-state intensity training, have been criticised as a part of the conditioning programmes of team sports players due to being non-specific, time

consuming, eliciting low motivation and incurring a greater incidence of overuse injuries due to an increased training volume (Brukner and Khan, 1994; Impellizzeri et al., 2006). High-intensity interval training (HIT) has been shown to be more effective in increasing maximal oxygen uptake ($\dot{V}O_{2max}$) than training at the lactate threshold (LT) or 70% maximal heart rate (HRmax) (Helgerud et al., 2007) and can be made sport-specific to team sports players, therefore increasing player motivation (Hoff et al., 2002).

1.3 Small-sided game conditioning

Noteworthy in recent years is the emergence of small-sided games (SSGs) as a multi-component training method, which allows the simultaneous development of physiological, technical and tactical aspects of team sports (Rampinini et al., 2007). Research has suggested that SSGs can elicit intensities suitable for aerobic development (above 90% HRmax; Helgerud et al., 2001; Helgerud et al., 2007) in a HIT format (Hoff et al., 2002; Impellizzeri et al., 2006; Little and Williams, 2006; Little and Williams, 2007; Mallo and Navarro, 2007; Rampinini et al., 2007a; Kelly and Drust, 2009). Studies have determined how manipulating SSG variables can increase the physiological, movement and technical demands of SSGs, such as altering SSG rules (Mallo and Navarro, 2007; Gabbett et al., 2010), reducing playing number (Aroso et al., 2004; Sassi et al., 2004), reducing playing area size (Tessitore et al., 2006); increasing playing area size (Barnes et al., 2008; Kelly and Drust, 2009; Casamichana and Castellano, 2010), reducing both player number and playing area size (Platt et al., 2001; Little and Williams, 2006; Little and Williams, 2007; Williams and Owen, 2007; Hill-Haas et al., 2009a; Katis and Kellis, 2009), reducing player number and increasing playing area size (Owen et al., 2004; Rampinini et al., 2007a) and including coach encouragement (Rampinini et al., 2007).

Small-sided games studies have been conducted with junior elite (Aroso et al., 2004; Impellizzeri et al., 2006; Jones and Drust, 2007; Gabbett, 2008a; Kelly and Drust, 2009; Gabbett et al., 2010), sub-elite (Casamichana and Castellano, 2010) and amateur players (Platt et al., 2001; Katis and Kellis, 2009), and senior elite (Mallo and Navarro, 2007; Kelly and Drust, 2009; Fanchini et al., 2011), sub-elite (Hoff et al., 2002; Little and Williams, 2006; Tessitore et al.,

2006; Little and Williams, 2007) and amateur players (Coutts et al., 2009; Fanchini et al., 2011). However, whilst there has been investigation into both junior and senior SSGs of all levels of play, there has been no investigation into the effect of age on the physiological and technical demands of SSGs, despite previous findings that junior RL players of different ages (<15 and <18 years) respond differently to a given training stimulus (Gabbett et al., 2008b).

It is important for coaches to be confident in the ability of SSGs to provide a consistent aerobic training stimulus. Little and Williams (2006, 2007) have reported small differences in the test-retest HR responses of soccer SSGs (coefficient of variation [CV] less than 3% maximal heart rate [HR_{max}]), suggesting good reliability. Likewise, Hill-Haas et al. (2008) reported good test-retest reliability of HR and movement demands in soccer SSGs (technical error less than 5% mean HR responses). However, despite a heightened interest in SSG research in recent years, few studies have considered the reliability of the physiological responses to SSG training methods. Moreover, Rampinini et al. (2007) found soccer SSGs to have moderate to poor reliability of physiological and perceptual responses (CV values of 2-4.8, 20.5-43.7 and 6.2-31.9 for HR, blood lactate and RPE responses, respectively). Thus, further investigation into the repeatability of SSG responses is warranted.

1.4 Aims and scope of thesis

Whilst the effects of manipulating rules, playing number, playing area size and coach encouragement on the demands of SSGs have been determined, they have rarely been examined in isolation and, importantly, scrutiny has tended to be confined to the game of soccer. Thus, the physiological and technical responses to RL SSGs and how these responses are affected by altering the variables mentioned above are undetermined. In the same vein, although the reliability of soccer SSGs has been examined, the repeatability of RL SSGs on a test-retest basis has yet to be examined and it is therefore unclear if such games produce consistent stimuli (sufficient to elicit aerobic adaptations) on a trial to trial basis. Therefore, the first study of this thesis identifies the heart rate (HR) responses to a SSG commonly utilised in RL conditioning sessions in two

different junior age groups, and examines the effects of manipulating the player number and playing area size on those responses. In addition, the repeatability of the HR responses across two trials is established.

Rampinini et al. (2007) reported that soccer SSGs with coach encouragement elicited greater physiological demands than SSGs without coach encouragement, possibly due to increased external motivation and competitiveness (Mazzetti et al., 2000; Coutts et al., 2004; Gentil and Bottaro, 2010). However, there has been no research into the effect of coach encouragement on the technical demands of soccer SSGs or the physiological and technical demands of RL SSGs. Of equal importance, no studies have examined the physiological or technical demands of attacking and defending player roles. Thus, the second study of this thesis examines the effect of altering player role (attack versus defence) and coach's role (with coach encouragement versus without coach encouragement) on the HR and technical demands of RL SSGs in two junior age groups. Again, the repeatability of the HR responses across two trials is also evaluated.

Therefore, the aims of this thesis are to (i) determine and identify the physiological and technical demands of RL-specific SSGs, (ii) examine if these demands are affected by manipulating SSG variables, specifically; player number, playing area size, coach role and player role, and (iii) establish if there are any differences between SSG demands between two junior age groups and, (iv) assess the repeatability of the HR demands of SSGs. It is intended that the findings from this research will be communicated to RL coaches and coach educators in a manner that will inform their knowledge and practice of conditioning for the game.

Chapter 2.0 Review of Literature

2.1 The physiological demands of rugby league

Rugby league (RL) players require high levels of aerobic power, muscular strength, power, agility and speed due to the demanding physiological requirements of the game (Gabbett, 2005d; Gabbett et al., 2008a). The physiological qualities of players have been shown to increase as the standard of play increases (Gabbett, 2000; Meir et al. 2001b; Gabbett, 2002a, 2002b), and accordingly, those of professional RL players are reported to be well developed as a result of their demanding training schedules (Gabbett et al., 2008a). Furthermore, the introduction of rule changes (Meir et al., 2001; Gabbett, 2005e), the influx of overseas players and coaching methods and a shift to summer rugby in the United Kingdom since 2000 have raised these demands significantly at the highest level.

Rugby league requires considerable contributions from both the aerobic and anaerobic energy systems due to the intense, intermittent nature of the game (Coutts et al., 2003). For example, Coutts et al. (2003) analysed a single competitive match involving 17 semi-professional RL players in which a mean capillary blood lactate concentration of $7.2 \pm 2.5 \text{ mmol l}^{-1}$ was reported from samples taken at specific stages throughout play. Notwithstanding individual variability, this high blood lactate concentration would suggest a high anaerobic contribution to competitive RL. Coutts et al. (2003) also reported mean match oxygen consumption ($\dot{V}O_2$) values of $81.1 \pm 5.8\%$ of maximal values ($\dot{V}O_{2\text{max}}$) in semi-professional RL matches. In addition, average heart rate (HR) values equating to $84.3 \pm 4.8\%$ (Coutts et al., 2003) and $86.7 \pm 4.4\%$ (Estell et al., 1996) of maximal values (HR_{max}) have also been reported in semi-professional and elite junior matches, respectively, and players have been reported to spend a significantly greater amount of time in moderate ($39.7 \pm 12.6\%$) and high intensity activity ($44.4 \pm 15.9\%$) compared to low intensity activity ($15.9 \pm 19.5\%$) (Coutts et al., 2003). Collectively, although the above data are now relatively dated and were recorded from single RL matches, they indicate that competitive RL is intense and consequently, the aerobic and anaerobic demands during competition are relatively high.

More recent research has reported elite players to cover distances of $8,503 \pm 631$ m during a match, with positional values ranging from $8,142 \pm 630$ m (outside backs) to $8,800 \pm 581$ m (pivots) and prop and back row players covering $8,688 \pm 405$ m and $8,685 \pm 547$ m, respectively (Sykes et al., 2009). Although following the same positional patterns of distance covered within a RL match, King et al. (2009) reported professional RL players to cover lower distances, ranging from $4,310 \pm 251$ m (props and second row) to $6,265 \pm 318$ m (outside backs) (King et al., 2009). This discrepancy could in part be due to differences in the time motion analysis methods employed; Prozone, a semi-automated image recognition system, and a hand notation system were utilised by Sykes et al. (2009) and King et al. (2009), respectively.

Rugby league players require high levels of aerobic fitness to be able to repeatedly perform high intensity movements, as aerobic fitness has been shown to benefit recovery from high intensity efforts (McMahon and Wenger, 1998; Tomlin and Wenger, 2001; Tomlin and Wenger, 2002; Bishop et al., 2004) through enhanced oxygen uptake kinetics, improved lactate removal and better phosphocreatine regeneration (Tomlin and Wenger, 2001). Further, Spencer et al. (2004) have suggested that repeated sprint ability (RSA) is an important facet of team sports performance. However, Sirotic et al. (2009) reported no differences in sprint data between elite and semi-elite RL competition, with mean sprint durations of 2.1 ± 1.2 and 2.0 ± 0.9 s, durations between sprints of 7.7 ± 5.0 and 9.3 ± 5.5 s and duration between sprinting bouts of 3.9 ± 1.6 and 4.2 ± 1.9 min, respectively. Interestingly, Sirotic et al. (2009) found repeated sprint bouts to be rare within RL, as they observed an average between 0 and 3 bouts across 30 matches. However, the authors suggest rugby-specific repeated bout training should be employed by RL coaches as repeated sprint efforts can occur at critical time points within competition, such as successive tackles or collisions (Spencer et al., 2004). Moreover, previous studies have shown a moderate correlation between aerobic fitness and RSA in untrained to moderately trained subjects (r ranging from 0.42 to 0.66; Dawson et al., 1993; McMahon and Wenger, 1998; Bishop et al., 2004). In contrast, weaker correlations have been reported in trained team sports players (r ranging from -0.15 to 0.35), suggesting that factors developed

through team sports training other than aerobic fitness are important to RSA (Bishop and Spencer, 2004). However, there is limited evidence to determine the factors which limit RSA and consequently how RSA might be improved (Bishop et al., 2004).

Gaitanos et al. (1993) examined muscle metabolism in an exercise sprint test protocol specific to the movement demands of team sports of 10 x 6 s sprints interspersed with 30 s rest. No change was found in muscle lactate levels, although there was only a 73% reduction in mean power output from the tenth and last sprint in comparison to the first sprint. In addition, phosphocreatine concentration decreased to 57% and 16% of resting values following the first and last sprint, respectively, suggesting that phosphocreatine stores are not fully replenished within 30 s following a 6 s sprint. Similar findings have been reported by Dawson et al. (1998) who reported a reduction of 45% in phosphocreatine stores from resting concentration following 24 s recovery from 6 s cycle sprints. Together, the above studies demonstrate a decreased reliance on anaerobic metabolism across short repeated sprints, and therefore a greater contribution from aerobic processes in order to support exercise of this nature. Consequently, it might be assumed that a well developed aerobic system and repeated sprint ability are important factors in RL performance.

Studies have reported RL players to have estimated $\dot{V}O_{2\max}$ values between 42 to 53.5 ml·kg⁻¹·min⁻¹ (Table 2.1). Gabbett (2002a) found Australian first, second and third grade players to have similar mean estimated $\dot{V}O_{2\max}$ values, ranging from 45.5-48.5 ml·kg⁻¹·min⁻¹. Other studies have reported senior sub-elite mean estimated $\dot{V}O_{2\max}$ values in the range of 43-52 ml·kg⁻¹·min⁻¹ and elite junior and sub-elite values ranging from 45-50 ml·kg⁻¹·min⁻¹ and 43-50 ml·kg⁻¹·min⁻¹, respectively (Table 2.1). These $\dot{V}O_{2\max}$ values are lower than previously reported in other team sports, with values ranging from 52-55 and 57-64 ml·kg⁻¹·min⁻¹ reported in elite rugby union (Mayes and Nuttall, 1995; Deutsch et al., 1998; O’Gorman et al., 2000) and soccer (Wisløff et al., 1998; Helgerud et al., 2001; Reilly and White, 2004), respectively. However, the aforementioned RL studies have estimated $\dot{V}O_{2\max}$ from the level achieved in the multi-stage fitness test (MSFT; see Table 2.1), possibly due to practical issues of assessing

$\dot{V}O_{2\max}$. Whilst the MSFT might be considered practical when testing large groups of players, Twist et al. (2007), have shown the MSFT to consistently underestimate $\dot{V}O_{2\max}$ by $5.24 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ in high-level junior RL players (values of $52.1 \pm 5.2 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ versus $57.3 \pm 6.6 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ reported from a MSFT and treadmill based assessment of $\dot{V}O_{2\max}$, respectively). Similar levels of aerobic fitness have been reported between forwards and backs in semi-professional RL players ($45\text{-}50 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$; Gabbett, 2002a, Gabbett, 2002b), which suggests positional specific conditioning does not occur at this level. However, at higher standards of play, props have been shown to have lower estimated $\dot{V}O_{2\max}$ values than players in other positions among professional (Meir et al., 2001b), sub-elite (Gabbett, 2006c; Gabbett and Herzig, 2004) and junior elite players (Gabbett and Herzig, 2004).

Table 2.1: Estimated $\dot{V}O_{2\max}$ of RL players (values are mean \pm SD unless otherwise stated)

Study	Level of play	Phase of season	Age (y)	Estimated $\dot{V}O_{2\max}$ (ml·kg ⁻¹ ·min ⁻¹)
Gabbett (2002a)	Senior sub-elite	Competitive	(first grade, second grade, U19)	Range = 43.9 - 50.1
	Junior sub-elite	Competitive	(U16, U15, U14, U13)	Range = 32.1 - 49.5
Gabbett (2002b)	Semi-professional	Pre-season	24 \pm 4	46 \pm 4.4
Gabbett (2004)	Sub-elite	Pre-season 2001	22.9 (CI: 20.7-25.1)	47.2 (CI: 45.1-49.3)
		Pre-season 2002	19.6 (CI: 18.4-20.8)	45.5 (CI: 43.4-47.6)
		Pre-season 2003	21.5 (CI: 19.6-23.4)	48.5 (CI: 46.1-50.9)
Gabbett and Herzig (2004)	Junior elite	Competitive	U15, U16, U17	49.3 (Range: 48.4-50.6)
Gabbett (2005a)	Amateur	Off-season	>18	42.0 (CI: 38.8-45.1)
		Pre-season		48.5 (CI: 46.1-50.9)
		Mid-season		51.3 (CI: 49.6-52.9)
		End-season		49.6 (CI: 47.5-51.7)
Gabbett (2005b)	Non-elite	Off-season	17.9 (SE: 0.4)	43.7 (CI: 39.9-47.5)
		Pre-season		50.6 (CI: 48.5-52.8)
		Mid-season		53.5 (CI: 51.7-55.3)
		End-season		52.1 (CI: 50.5-53.8)
Gabbett (2006a)	Junior sub-elite	Pre-season	16.9 (CI: 16.7-17.1)	50.3 (CI: 48.5-52.1)
	Senior sub-elite		25.5 (CI: 23.6-27.3)	47.2 (CI: 44.8-49.6)

U= under, CI = confidence interval, SE = standard error, SEM = standard error of measurement

Table 2.1 continued: Estimated $\dot{V}O_{2\max}$ of RL players (values are mean \pm SD unless otherwise stated)

Study	Level of play	Phase of season	Age (y)	Estimated $\dot{V}O_{2\max}$ (ml·kg ⁻¹ ·min ⁻¹)
Gabbett (2006b)	Sub-elite	Competitive (SSG)	22.3 (SE: 0.8)	52.2 (SE: 0.5)
		Competitive (Traditional)	22.1 (SE: 0.9)	48.8 (SE: 0.4)
Gabbett (2006c)	Sub-elite	Competitive	22.3 \pm 5.0	45.6 \pm 6.5
Gabbett et al. (2007)	First Grade	Competitive	23.7 \pm 4.3	46.9 \pm 5.8
	Second Grade		24.4 \pm 5.0	45.6 \pm 5.7
	Third Grade		17.8 \pm 1.5	47.6 \pm 7.6
Twist et al. (2007)	Junior sub-elite	Not reported	14.4 \pm 1.2	52.1 \pm 5.2
Gabbett et al. (2008b)	U18 elite	End of pre-season	16.9 \pm 0.3	45.2 \pm 1.2
	U15 elite	End of pre-season	14.1 \pm 0.2	48.8 \pm 1.1
Gabbett (2009)	Junior elite	Competitive	16.0 \pm 0.2	48.2 \pm 4.6
	Junior sub-elite		15.9 \pm 0.6	43.3 \pm 5.4
Till et al. (2011)	Junior regional	Competitive	U13, U14, U15	48.7 \pm 5.2
	Junior national	Competitive	U13, U14, U16	50.3 \pm 3.8

U= under, SE = standard error, SEM = standard error of measurement

2.2 The technical demands of rugby league

A technical analysis is commonly conducted using a set of performance indicators, which can be any parameter, movement variable or action that contributes to performance or skill execution. Although time-motion analyses within team sports have largely focused on the analysis of movement demands, far less scrutiny has been given to performance indicators, where closed skills are usually categorised as either scoring indicators or indicators of skill quality (Hughes and Bartlett, 2002). It is difficult to compare results across some studies as different descriptive statistics of frequency data have been reported. Some of the earlier studies have reported mean and standard deviation values, whereas median values have been deemed a more appropriate measure of central tendency in non-typical data (Eaves et al., 2005). More recent studies analysing rugby union performance have reported median values in conjunction with 95% confidence limits (Prim et al., 2006; Jones et al., 2004; James et al., 2005), range (van Rooyen et al., 2006, 2008a) and inter-quartile range (Jones et al., 2008). To report frequency statistics appropriately and to allow comparison to previous studies, Eaves et al. (2005) have suggested reporting both frequency mean and median values with technical data, although both measures are seldom reported (Ortega et al., 2009; Eaves et al., 2005). There are also issues with the statistical analyses conducted on frequency data. A few studies have employed parametric tests with non-typical frequency data (McKenzi et al., 1989; Hughes and White, 1997) or have failed to report the statistics utilised (Stanhope and Hughes, 1997).

Whilst studies have established and assessed the technical demands of rugby union competition (McKenzie et al., 1989; Hughes and White, 1997; Stanhope and Hughes, 1997; Smythe et al., 1998; Vivian et al., 2001; Eaves and Hughes, 2003; Jones et al., 2004; Eaves et al., 2005; James et al., 2005; van Rooyen et al., 2006; Ortega et al., 2009; Vaz et al., 2010; Vaz et al., 2011), performance indicators are less researched and therefore established within RL (Eaves and Broad, 2007; Eaves and Evers, 2007; Eaves et al., 2008). The majority of studies have compared the performance indicators of

winning and losing teams (Hughes and White, 1997; Stanhope and Hughes, 1997; McCorry et al., 2001; Jones et al., 2004; James et al., 2005; Prim et al., 2006; van Rooyen et al., 2006, van Rooyen et al., 2008b; Ortega et al., 2009; Vaz et al., 2010; Vaz et al., 2011). However, these studies have investigated the success of full games, which is not representative of changes in performance within critical phases within the match (Eaves and Evers, 2007).

Jones et al. (2004) constructed a performance profile of a professional rugby union team across a season consisting of 20 matches, in which the indicators of scrums, lineouts, rucks, mauls, tackles, passes, kicks, breaks, turnovers, tries scored, penalties conceded and errors were examined. Successful performances were generally characterised by higher percentage success rates. However, the study examined only the confrontation between two teams, of which one was always the same team, winning teams were found to gain a greater amount of ball possession from the opposition's line-out. A study by James et al. (2005) examined similar performance indicators within rugby union competition within positional roles and groups. They reported intra-positional differences, which the authors suggested were due to variations in individual style of play and decision making. However, again, only one team's matches across a season were examined and the sample size within each positional group ranged from 1 to 5 players. Moreover, Jones et al. (2004) and James et al. (2005) researched club level rugby and not international competition. Van Rooyen et al., (2006) compared the performance variables (frequency of tries, conversions, penalties, drop goals, scrums, possession and territory) of South Africa to the top three nations (England, Australia, New Zealand) in the 2003 Rugby Union World Cup. Their findings suggested that successful teams have more ball possession and score more points in the second half. However, although a reliability analysis was conducted, the results were not reported. Van Rooyen (2008b) subsequently conducted a similar study on the teams who reached the semi-finals versus the quarter-finals in the 2005 Rugby World Cup Sevens. The successful (semi-final) teams maintained possession for between 30-60 seconds and were able to score from at least 30% of ball possessions.

Ortega et al. (2009) examined aspects of scoring, phases of play and game development in 58 Six Nation matches from 2002-2006. The results demonstrated that winning teams have more ball possession; especially in scrums and lineouts, utilise the maul more in attack and complete more tackles in attack. However, no reliability analyses were reported. Similar studies that have carried out comprehensive analyses of rugby union World Cup, Six Nations, Tri Nations and Super 12 games from 2003-2006, reported no significant differences between winning and losing teams when the final score was close (Vaz et al., 2010, Vaz et al., 2011). However, northern versus southern hemisphere teams were included in some of the analyses, notwithstanding previous findings of differences in playing styles between northern and southern hemisphere teams (Eaves and Broad, 2007). In contrast to the above studies that have evaluated success from match outcome alone, Jones et al. (2008) assessed success through team performance indicators, comparing two professional teams' performances to their current and previous form across the season (preceding 5 and 19 games, respectively). This method proved to be interesting from a coaching perspective, as one team was shown to win their match despite performing at a lower level than their previous matches, whereas another team lost their match but performed at a higher standard in some areas.

The frequency of ball retention in contact situations has also been investigated within rugby union performance research (McKenzie et al., 1989; Smyth et al, 1998; Prim et al., 2006). However, this investigation is limited considering the high prevalence of contact situations within rugby union. McKenzie et al. (1989) reported that successful teams are able to retain the ball more in contact situations in international play. Moreover, Smyth et al. (1998) reported that the most successful ball-carrier action into contact is turning towards support players from a low body position. Subsequent studies have examined the frequency and success rate of aspects of contact situations, namely; ruck and maul success as well as successful tackles made (Jones et al., 2004; 2008), tackle success (James et al., 2005) and ruck and maul frequency (Eaves et al. 2005). However, detailed information of contact situations are not reported in the aforementioned studies. Prim et

al. (2006) conducted a more comprehensive analysis of international rugby union performance in the 2005 Super 12 Competition. The performance indicators analysed included recycle time (time between ball-carrier being held and the ball becoming available), fast ball obtained and conceded (frequency ball obtained and conceded from tackle situations in less than three seconds) and unsuccessful tackles made as well as indicators of the time taken to offload the ball and turnover a tackle. No differences in any indicators were found, although the game sample size was small, thus, possibly increasing the risk of a type II error and missing significant findings. Moreover, the aforementioned studies have used inconsistent definitions of contact. Consequently, van Rooyen et al. (2008a) classified and examined the frequency of 10 different types of contact involving impact in open play, with the ground and in scrums, rucks lineouts, tackles and mauls within professional rugby union matches. The most frequent contact observed was with the ground, followed by scrums and differences were found between the number of contact situations in forward and backline players.

As mentioned previously, although rugby union has received extensive analysis of performance, there has been limited investigation into RL performance. Eaves and Broad (2007) compared the playing patterns (pitch area, type of tackle and attacking run post-ruck) between English Super League (SL) and Australian National Rugby League (NRL). The post-ruck movements analysed included tactical kick, dummy run (a run with the ball from the PTB), hit-up (a single pass to a player who carries the ball in contact) and pass play (two or more passes before the ball is carried into contact). The contact situations of single, combination and turtle tackles (player turned on back) were examined, which is quite a basic analysis of contact situations in comparison to recent rugby union research (van Rooyen et al., 2008a) and the tackle classifications were not described. Nonetheless, Eaves and Broad (2007) reported NRL teams carried out a greater number of turtle tackles. Differences were also reported in playing patterns and movements post-ruck demonstrating different playing tactics between English and Australian RL. The same attacking run classifications were used in a

later study in professional RL, in which play-the-ball (PTB) speed and the position of the attack were found to be factors associated with creating perturbations in play (Eaves and Evers, 2007). However, Eaves and Broad, (2007) and Eaves and Evers (2007) examined only 6 games in each hemisphere and in total, respectively.

2.3 Monitoring team sports training

It is important to monitor team sports training in order to determine the physiological and technical demands placed on players and to help identify and monitor both individual and team training goals. Common methods of examining the exercise demands of training include HR monitoring, ratings of perceived exertion (RPE), assessment of blood lactate and notational analysis.

2.3.1 Ratings of perceived exertion

The use of RPE within team sport training is a cost effective method of obtaining subjective, self-reported assessments of exercise intensity, especially if HR monitors are not practical or available (Borresen and Lambert, 2009). However, RPE is limited due to being a subjective measure of intensity and studies have found RPE to be affected by the external training load (Impellizzeri et al., 2005), training status (Robertson and Noble, 1997), over-training (Snyder et al., 1993) and any factors which contribute to the personal perception of physical effort, such as hormone concentration, substrate concentration, personality traits, ventilation rate, neurotransmitter levels, environmental conditions and psychological states (Borresen and Lambert, 2009).

2.3.2 Blood lactate analysis

The assessment of blood lactate concentration during team sports competition and training is problematic due to sampling issues, despite the development of valid and reliable portable analysis systems (Bishop, 2001; Pyne et al., 2000). Moreover, aspects of training such as muscle glycogen concentration (Swart and Jennings, 2004), muscle tissue damage (Asp et al.,

1998; Swart and Jennings, 2004) improvements in training status and over-training (Jeukendrup and Hesselink, 1994; Urhausen et al., 1998) have been shown to affect blood lactate concentration. Therefore, the analysis of blood lactate concentration has limited value for monitoring training intensity (Borresen and Lambert, 2009).

2.3.3 Heart rate analysis

The theoretical justification for assessing training intensity via HR monitoring is the linear relationship and positive correlation observed between HR and $\dot{V}O_2$ in steady-state sub-maximal exercise (Åstrand and Rodahl, 1986; Haskell et al., 1993; Kay et al., 1995). However, the HR- $\dot{V}O_2$ relationship is curvi-linear both towards maximal and low exercise intensities (Davies, 1968) and can result in an 8-12 b·min⁻¹ standard deviation of the estimation of HRmax (Whaley et al., 1992; Miller et al., 1993). Furthermore, the use of HR monitoring within team sports has been questioned due to the non-steady intermittent nature of such activities, with sudden changes in work load not reflected in the slower changes in HR (Tumilty, 1993; Achten and Jeukendrup, 2003; Impellizzeri et al., 2005). Additionally, caution is needed when assessing training intensity via HR monitoring due to HR being sensitive to emotional stress (Coutts et al., 2003), as well as physiological and environmental factors (Achten and Jeukendrup, 2003).

Despite the aforementioned limitations, HR analysis has prevailed in individual sports and is becoming more widely used within team sports through the development of team HR systems. Moreover, HR monitoring is an objective method of measuring exercise intensity in comparison to assessments of RPE and is a more valid method of measuring intensity than blood lactate assessment. In addition, HR measurement has been found to be a reliable assessment of intensity within soccer specific conditioning through small-sided games (SSG) (Little and Williams, 2006; Tessitore et al., [2006; Little and Williams, 2007, Hill-Haas et al., 2008). Therefore, the majority of team sports research has utilised HR analysis, in which HR intensity is commonly presented as a percentage of maximal HR (%HRmax)

or categorised into discrete HR zones from which training intensity can be prescribed

2.3.4 Notational Analysis

Notational analysis examines actual sports performance within competition and training environments (O'Donoghue, 2010). The purpose of notational analysis has been categorised as tactical evaluation, technical evaluation, analysis of movement, performance modelling and coach and player education (Hughes and Bartlett, 2008). The majority of notational analysis research within team sports has been from a technical viewpoint of investigating open skills in team sports (Hughes and Bartlett, 2004).

The simplest method of notational analysis involves hand notation systems in which performance indicators are tallied by hand during competition or training. Advancements in computer technology have led to computerised notational analysis of sport which can integrate video footage and performance databases (O'Donoghue, 2010). Both hand notation and computer-based notation systems raise inter- and intra- observer reliability concerns due to the subjective method of producing data. Consequently, inter- and intra- operator reliability is often examined using an acceptable percentage error of less than 5% or 10%. Moreover, computer-based systems increase the possibility of operator and software errors, although attempts to minimise these errors can be made through validating notation systems (Hughes and Franks, 2004). Thus, computer-based systems, such as Sports Code, remain a common method of notation during both live matches and within post-match analysis.

2.4 Aerobic conditioning for team sports

Section 2.1 demonstrated that RL players require high aerobic fitness to assist in the recovery from the intermittent repeated sprint nature of the game and to be able to endure the reported distances covered within a match. Thus, aerobic conditioning could be assumed to be an essential part of RL training programmes. The effectiveness of aerobic conditioning achieved

from a conditioning programme is determined by the interaction of various training principles: exercise intensity, duration of the conditioning sessions and conditioning programme, frequency of sessions and the initial aerobic fitness level of the athlete (Wenger and Bell, 1986; Smith, 2003).

2.4.1 Traditional team sports conditioning

Traditional aerobic conditioning methods, such as continuous steady state intensity training, have been criticised as being a part of the conditioning programmes of team sports players due to being non-specific, time consuming and less motivating than more recent aerobic conditioning methods (Impellizzeri et al., 2006) such as small-sided games (see section 2.6). Moreover, such methods might be expected to incur a greater incidence of overuse injuries due to the increased training volume (Brukner and Khan, 1994). Indeed, a recent study has reported a significant relationship between training load and incidence of injury in professional RL players ($r=0.82$; Gabbett and Jenkins, 2011), suggesting the incidence of injury increases as training load increases.

A meta-analysis conducted by Londeree (1997) on the effect of training on lactate threshold (LT) demonstrated that trained and untrained endurance athletes do not elicit the same training response from sub-maximal continuous exercise and concluded that trained performers require a higher exercise intensity (above 80% $\dot{V}O_{2max}$) to achieve further increases in $\dot{V}O_{2max}$ compared to untrained performers. In the same vein, a longitudinal study reported an increase in $\dot{V}O_{2max}$ in highly trained skiers ($\dot{V}O_{2max} > 65 \text{ ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) when the volume of high intensity training (LT or higher) increased from 6% to 25% of total training time. The skiers' $\dot{V}O_{2max}$ increased from 65.9 to 69.3 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ and 65.5 to 71 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$ in the pre-competition and competition phases of the season, respectively. Whilst the aforementioned studies are not directly related to team sports players, they demonstrate that highly trained performers may require a high training intensity to obtain further improvements in $\dot{V}O_{2max}$ and therefore support the use of HIT within team sports training.

2.4.2 High-intensity interval training

Laursen and Jenkins (2002) defined HIT as 'repeated bouts of short to moderate duration exercise completed at an intensity which is greater than the anaerobic threshold'. Expanding on Londeree's (1997) findings that trained athletes require a higher exercise intensity to achieve further increases in $\dot{V}O_{2\max}$, the rationale behind HIT is to achieve an optimal training stimulus to increase aerobic performance through training at, near or above $\dot{V}O_{2\max}$ (Laursen and Shing, 2002). There is little distinction in the literature between intervals of short sprint (5-120 s) and moderate duration (3-8 minutes), with both training methods often interchangeably referred to as HIT. Further, there has been limited investigation into the effectiveness of acute high intensity training programmes or the underlying physiological mechanisms with highly trained athletes (Hawley et al., 1997; Kubukeli et al., 2002) mainly due to elite athletes not being forthcoming in volunteering for such studies (Hawley et al., 1997). Interestingly, the majority of literature that has analysed moderate duration interval HIT of four minutes or above has used a SSG training method with team sports players. From this point forward, unless otherwise stated, HIT will refer to moderate duration interval training (3-8 minutes), as relevant to this thesis.

Earlier HIT studies were carried out in cycling in which trained cyclists produced five minute intervals at 80% peak power output (PPO), with one minute recovery between bouts for four (Lindsay et al., 1996; Weston et al., 1997), six (Westgarth-Taylor et al., 1997) and seven weeks (Hawley et al., 1997). Although no HR data were reported within the training programmes, making direct comparison to the majority of interval conditioning studies problematic, the interval training increased PPO, 40 km cycle time trial performance (Lindsay et al., 1996; Hawley et al., 1997; Weston et al., 1997; Westgarth-Taylor et al., 1997), time to fatigue at 150% PPO (Lindsay et al., 1996; Weston et al., 1997; Westgarth-Taylor et al., 1997) and skeletal muscle buffering capacity (Weston et al., 1997). A subsequent cycling HIT study with trained cyclists examined five different interval training programmes with interval durations and intensities ranging from 30 s to eight minutes and 175-80% PPO, respectively (Stepto et al., 1999). Two of the HIT formats were

found to be the most effective in increasing PPO and 40 km time trial performance, namely, 8 x 4 minutes at 85% PPO with 90 s recovery and 12 x 30 s at 175% PPO with 4.5 minutes recovery. However, the sample size in each training group was small ($n=4$) and the training response was reported to be variable.

A recent study compared the effectiveness of four common training interventions on moderately trained male subjects who participated in physical activity three times per week. The training interventions included low intensity distance running at 70% HRmax for 45 minutes, LT running at 85% HRmax for ~24 minutes, 15 s intervals at 90-95% HRmax with 15 s rest, 4 x 4-minute intervals at 90-95% HRmax with three minutes of active recovery at 70% HRmax (Helgerud et al., 2007). Greater increases in $\dot{V}O_{2max}$ and SV were found in both the HIT training methods (15 s sprints and 4 x 4-minute intervals) compared to the long distance and LT training methods ($P<0.01$), suggesting improvements in $\dot{V}O_{2max}$ were due to increased cardiac output (\dot{Q}) as a result of increased SV. An earlier study by the same lead author (Helgerud et al., 2001) compared changes in $\dot{V}O_{2max}$ and soccer performance (distance covered, number of sprints, passes and involvements with the ball) following an eight week running HIT training method using the above format of four minute intervals interspersed with three minutes of active recovery against a control group carrying out extra technical training practices with the ball such as heading, free kicks and passing practices for the same duration. The HIT training increased $\dot{V}O_{2max}$ by 10.8% (58.1 to 64.3 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) and LT by 16% (47.8 to 55.4 $\text{ml}\cdot\text{kg}^{-1}\cdot\text{min}^{-1}$) ($P<0.01$), whereas there was no significant difference in any of the measurements for the control group, suggesting that the HIT format used can be an effective aerobic conditioning approach. In addition, there was a significant ($P<0.05$) increase in soccer performance in the training group reflected by a 24.1% increase in involvements with the ball (47.4 to 58.8), 100% increase in the number of sprints (6.2 to 12.4) and a 20% increase in the total distance covered (8,619 to 10,335 m). Although these results were based on a single match following the training programme, the findings provide tentative evidence to suggest

that fitness gains from this type of interval training are associated with game-specific fitness and performance improvements. Collectively, the fitness and performance results show that HIT increased aerobic and match performance more than soccer training alone and may be an appropriate training method for other team sports players.

There has been little investigation into the recovery duration between interval bouts within HIT in trained athletes. Some studies have either used either a fixed WRR, for example, 2:1, 1:1, 1:2 (Billat et al., 1999) or the duration of the time taken for HR to decrease to a set %HRmax (Acevedo and Goldfare, 1989; Driller et al., 2009). Few studies have directly assessed the effect of different recovery durations within HIT using moderate duration intervals on physiological variables (Seiler and Hetlelid, 2005). Seiler and Hetlelid (2005) examined the difference in $\dot{V}O_2$ and blood lactate within HIT of varying recovery periods. Well-trained male runners carried out 6 x 4-minute intervals at their highest possible running velocity with 1, or 2 or 4-minute recovery periods between intervals. Surprisingly, there was no difference in interval performance with different recovery durations. However, no differences were reported in average HR or average running velocity selected for each interval regardless of recovery duration (83, 85 and 84% of $v\dot{V}O_{2max}$ for 1, 2 and 4-minute intervals respectively), possibly due to participants self-pacing their intervals.

Sports-specific conditioning methods have been incorporated into team sports training sessions to produce time efficient training in a game-specific environment. As team sports are intermittent in nature, a variation on HIT has been proposed for several team sports in the form of sports-specific circuits (Hoff et al., 2002, Chamari et al., 2005; McMillan et al., 2005) and SSGs (Hoff et al., 2002; Impellizzeri et al., 2006; Rampinini et al., 2007; Hill-Haas et al., 2009a). Hoff et al. (2002) devised a specific dribbling track (described as the 'Hoff test') that incorporates acceleration, deceleration and changes of direction whilst dribbling a ball around a 30 m circuit. Chamari et al. (2005) reported a significant correlation between laboratory assessment of $\dot{V}O_{2max}$

and distance covered in the Hoff Test after ten minutes ($r=0.68$, $P<0.01$), suggesting that the Hoff test is dependent on an individual's aerobic fitness. Furthermore, Hoff et al. (2002) have determined that Norwegian first division soccer players elicit an average exercise intensity of 93.5% HRmax using the dribbling track in four-minute intervals interspersed with three minutes of active recovery.

The dribbling track has also been used as part of a ten week conditioning programme in full time professional academy soccer players (age 16.9 ± 0.4 y), which resulted in a 9% increase in $\dot{V}O_{2\max}$ ($P \leq 0.001$) without having an adverse training effect on strength, jumping ability or sprint performance (McMillan et al., 2005). However, the first six weeks of the 10-week training programme were carried out in the pre-season phase, following a six-week summer break from training. Thus, the phase of season possibly accentuated the increase in $\dot{V}O_{2\max}$ reported. Yet, both of the above validation studies of the Hoff circuit did not assess any soccer performance measures or include a control group for comparison. A similar study conducted an eight week training programme in the mid-season with 18 highly trained national soccer federation players (pre-training phase $\dot{V}O_{2\max}$ of 65.3 ± 5.0 ml·kg⁻¹·min⁻¹; Chamari et al., 2005). The players competed in weekly matches and had six training sessions per week, two of which were devoted to fitness training consisting of 4 x 4 minute intervals of the Hoff test and 4v4 SSGs interspersed with three minutes of active recovery. Following the mid-season eight-week training programme, the distance covered in the Hoff test and $\dot{V}O_{2\max}$ increased by 9.6% and 7.5%, respectively. However, it is unclear how much the HIT training increased these measures alone due to four other training sessions and weekly matches being completed in the training period. Nonetheless, the study further demonstrates that team sport specific HIT can increase aerobic fitness in highly trained soccer players. Collectively, these studies demonstrate that the Hoff dribbling track is able to elicit intensities consistent with those observed in HIT when carried out in the same format and is therefore an appropriate method for developing aerobic fitness in

soccer players. To date, there are no specific RL circuits based on specific movement pattern protocols from competitive RL.

2.4.3 The physiological adaptations from high-intensity interval training

As mentioned previously, the rationale behind HIT is to achieve an optimal training stimulus to increase aerobic performance through training at or near $\dot{V}O_{2\max}$ (Laursen and Shing, 2002), as trained athletes require a higher exercise intensity to achieve further increases in $\dot{V}O_{2\max}$ (Londeree, 1997). Thus, increases in $\dot{V}O_{2\max}$ are achieved through increasing the functional capacity of either maximal \dot{Q} or maximal arterial-mixed venous oxygen difference ($a-\dot{V}O_2$; Saltin and Rowell, 1980), in accordance with the Fick equation (Yamabe et al., 1997; Laffite et al., 2003). Increases in maximal \dot{Q} can be obtained through increases in maximal SV as a result of a volume overload induced increase in ventricular diastolic stretch and mass, increased resistance to ventricular emptying and increased end diastolic volume (Clausen, 1977; Woodiwiss et al., 1998; Ferreira et al., 2003). In addition, an increase in blood and plasma volume due to increased production of albumin (Gillen et al., 1991; Yang et al., 1998; Nagashima et al., 1999; Mischler et al., 2003) would increase SV (Coyle et al., 1990) by preventing reductions in cardiac filling, central venous pressure and mean arterial pressure (Sawka et al., 2000). Moreover, SV and mean arterial blood pressures have been reported to rise up to $\dot{V}O_{2\max}$ with increasing exercise intensity in trained athletes, further suggesting myocardial adaptations are achieved at intensities near $\dot{V}O_{2\max}$ (Gledhill et al., 1994; Warburton et al., 1999; Zhou et al., 2001). In one of the few studies to measure SV via echocardiography, Nottin et al. (2002) found trained pre-pubertal children (cyclists) to have a greater maximal stroke index (indicator of SV) than untrained pre-pubertal children in a maximal cycle test (63 ± 5 and 56 ± 5 ml·m², respectively). Equally, the trained children had a greater $\dot{V}O_{2\text{peak}}$ than the untrained children (58.5 ± 4.4 and 45.9 ± 6.7 ml·kg⁻¹·min⁻¹, respectively). The authors concluded the increases in $\dot{V}O_{2\text{peak}}$ in trained children were a

result of increased SV due to increased pre-load, decreases in after-load and cardiac hypertrophy (Nottin et al., 2002).

Research has suggested that trained athletes are more likely to elicit peripheral adaptations than central adaptations following HIT (Laursen and Jenkins, 2005). Possible peripheral adaptations to HIT in trained performers include an increase in muscle buffering capacity (Weston et al., 1997; Hawley et al., 1997; Laursen and Jenkins, 2002), a down regulation of cation pumps, biomechanical changes, adaptation of the central nervous and endocrine systems, increases in myoglobin, capillary density and fibre type characteristics (Laursen and Jenkins, 2002). Weston et al. (1997) and Hawley et al. (1997) found cycling HIT programmes of five-minute intervals increased muscle buffering capacity within highly trained cyclists. An increase in muscle buffering capacity has been previously established in classic sprint training research (Sahlin and Henriksson, 1984; Parkhouse et al., 1985). However, Weston et al. (1997) and Hawley et al. (1997) suggested that the buffering capacity of the muscle also contributes to performance in sub-maximal high intensity exercise (Hawley and Hopkins, 1995). Skeletal muscle capillarisation has been shown to increase $a\text{-}\dot{V}O_2$ (Andersen and Henriksson, 1977; Ingjer, 1979), as a result of increased capillary pressure from increases in blood flow velocity (Hudlicka et al., 1992) and type II muscle fibres reducing in size (Bishop et al., 2000). Interestingly, other mechanisms found to increase $a\text{-}\dot{V}O_2$ within untrained and moderately trained athletes have been shown to be unaltered in trained athletes, such as increases in muscle myoglobin, erythrocyte mass, haemoglobin mass and skeletal muscle fibre oxidative capacity, as the oxidative capacity of skeletal muscle exceeds the cardiovascular system's capacity during whole body exercise (Richardson, 2000).

2.5 The small-sided games approach to aerobic conditioning in team sports

To produce efficient training sessions, coaches of sports teams seek multiple component training methods to enable fitness, technical and tactical elements to be trained simultaneously (Rampinini et al., 2007). In recent years, SSGs have emerged as one such method, which, whilst generic in their function can be designed to adopt sport-specific principles in order to accommodate the rules, movement patterns and physical demands of a particular sport. In adopting this method, coaches are being persuaded that SSGs can be conducted at intensities sufficient to enable increases in aerobic fitness (Hoff et al., 2002). Additionally, SSGs provide a greater psychological stimulus than traditional conditioning methods (Gamble, 2004; Impellizzeri et al., 2006).

SSGs have long been used by coaches to create a 'learning through games' environment in which game awareness and decision making processes are developed through the principles of game play (Bunker and Thorpe, 1982). This approach has been labelled the Teaching Games from Understanding Model (TGfU) and is also referred to as 'Game Sense' in Australia and the 'Tactical Games Model' in America (Gordon, 2009). The main contrast to the traditional coaching model is that a game is introduced initially and then broken down into technical and skill components. Therefore, the TGfU model focus is solely on the development of skill and decision-making capabilities, with limited emphasis on player conditioning. However, the use of such an approach might be considered to underpin the more recent application of SSGs for the aerobic conditioning of team sport athletes.

2.5.1 Small-sided games format and intensity

In one of the first SSG studies, Hoff et al. (2002) stated that the training intensity of SSGs should be greater than the intensity elicited during competitive match play in order to facilitate conditioning. Moreover, a HIT format has been adopted using SSGs in soccer, rugby union, RL and volleyball (Table 2.2). The majority of soccer SSG studies have adopted a framework of four-minute SSGs (Hoff et al., 2002; Chamari et al., 2005;

Impellizzeri et al., 2006; Rampinini et al., 2007a; Barnes et al., 2008; Coutts et al., 2009; Kelly and Drust, 2009; Katis and Kellis, 2009) with three minutes of active recovery between games (Hoff et al., 2002; Chamari et al., 2005; Impellizzeri et al., 2006; Rampinini et al., 2007a; Coutts et al., 2009; Katis and Kellis, 2009). Although it is unclear where this HIT format originated from, it would appear it evolved from a running interval study which found four running intervals of four-minute durations at 90-95% HRmax, interspersed with three minutes active recovery, increased both physiological characteristics and soccer performance in elite junior soccer players, as described in section 2.4.2 (Helgerud et al., 2001). Subsequently, Hoff et al. (2002) stated that their pilot SSG research led to the inclusion of four-minute SSGs interspersed with three minutes active recovery to achieve at least three minutes of each four-minute SSG in the high-intensity zone above 90% HRmax. The authors reported sub-elite soccer players achieved this target intensity within 5v5 soccer SSGs (average intensity of 91.3% HRmax and 84.5% $\dot{V}O_{2max}$). However, goalkeepers were included in the 5v5 soccer SSGs and it is unclear if they were included in the analyses. Interestingly, Impellizzeri et al. (2006) determined that soccer players obtained the desired intensity of 90-95% HRmax after approximately one minute into four minute intervals of soccer SSGs ranging from 3v3 to 5v5. In addition, later studies found soccer SSGs utilising the aforementioned format of four minute intervals to provide an average SSG intensity above 90% HRmax in some conditions (see section 2.5.2), suggesting that the commonly adopted format of four-minute intervals with three minutes recovery is a suitable framework for the conditioning of soccer players.

There has been little examination of interval and recovery duration on the demands of SSGs, consequently, either the aforementioned SSG interval format, or a very similar format has been utilised in soccer SSGs studies. A recent study has analysed the physiological, perceptual and technical demands of two, four, and six-minute bouts of 3v3 soccer SSGs with goalkeepers (Fanchini et al., 2011). Interestingly, although the four-minute interval period elicited the highest HR intensity (89.5% HRmax), it was not significantly different from the two-minute interval SSGs (88.5% HRmax).

Conversely, the six-minute SSGs elicited a significantly lower HR to both the two and four-minute SSGs (87.8% HRmax). In addition, interval duration had no effect on CR10 RPE score or the technical demands, apart from a reduction in passes and successful passes in the six-minute SSGs, possibly due to fatigue or the players adopting a pacing strategy, thus, decreasing the interval intensity (Fanchini et al., 2011). Further analysis of the distances covered within time zones and number of sprints could possibly clarify these claims. Nonetheless, the authors suggested that a four minute bout is the most appropriate interval duration, as four-minute SSGs obtained the highest HR intensity and have been found to be long enough to elicit training adaptations, although a training study was not incorporated in the aforementioned study. Although this study was one of the few to recognise the importance of keeping variables constant to determine the effect of SSG interval duration on SSG intensity, such as the playing area size, number of players, recovery time and SSG rules, amateur and professional players from two teams were utilised and the authors did not specify if the SSGs were equally matched for playing level or remained mixed. In addition, unlike any other SSG study, the first minute of each SSG interval was removed from the analyses to account for 'HR ramp' at the beginning of the game (an increase in HR at the start of each interval following the recovery period). Consequently, the HRs were lower when the first minute was included in the analysis (82.4, 85.9, 85.6% HRmax for two, four and six-minute games, respectively), although statistical analyses were not conducted on these data. This adds concern to the moderate intensity achieved, possibly due to goalkeepers being included, although it is unclear if they were included in the 3v3 analyses.

An earlier study examined the physiological and technical responses to three and eight-minute 6v6 SSGs in small (30x40 m) and large (40x50 m) playing areas in Italian regional soccer players (Tessitore et al., 2006). The three-minute SSGs elicited a greater HR intensity across both playing area sizes, although there was only a significant difference between the HR responses of the large playing areas (three-minute SSGs elicited 62% and 57% HRmax in the small and large areas, respectively; eight-minute SSGs elicited 57% and

48% HRmax in the small and large areas, respectively). No differences were reported between SSG duration and blood lactate and the frequency of passes per minute. Whilst the study demonstrated that an increase in SSG duration to eight minutes decreased SSG intensity, it did not incorporate a four-minute duration SSG to allow comparison to the majority of previous SSG literature. Collectively, Fanchini et al. (2011) and Tessitore et al. (2006) show that the interval duration of SSGs within a HIT has an impact on the intensity achieved and therefore the training load. Moreover, their findings suggest that six and eight-minute intervals are too long to achieve a high SSG intensity and further support the use of four-minute SSG intervals, in agreement with the HIT literature previously presented (Helgerud et al., 2001, Helgerud et al., 2007). Further investigation is required to determine if similar durations, such as three or five-minute intervals elicit a similar intensity and the impact of altering the recovery durations on SSG intensity.

Studies have quantified an intensity above 90% HRmax to be 'high-intensity' within soccer SSGs (Hill-Haas et al., 2009a; Hill-Haas et al., 2009b; Hill-Haas et al., 2009c; Casamichana and Castellano, 2010; Hill-Haas et al., 2010). Hill-Haas et al. (2009b) reported no differences in the time spent in any HR zone between a soccer SSG training programme and a generic HIT programme consisting of short duration sprints, repeated sprints, speed and agility drills (<60 s). However, the majority of time was spent in the low intensity zone in both training programmes and consequently, the programmes did not increase players' MSFT performance or $\dot{V}O_{2\max}$ (Hill-Haas et al., 2009b). Possible reasons for the low intensity elicited in the SSG and generic training programmes could be due to the 6-13 minute SSG interval duration incorporated, which was considerably longer than the suggested four-minute intervals (Hoff et al., 2002) and the short duration intervals (<60 s), respectively, creating more rest periods. However, the individual interval intensity data were not reported. Nonetheless, the classification of 'high-intensity' above 90% HRmax within SSGs further supports a target HIT interval intensity greater than 90% HRmax for aerobic development.

Some studies have reported soccer SSGs to elicit above 90% HRmax in SSGs of different formats to the aforementioned four-minute intervals and three minutes recovery (see section 2.5.2), although inconsistent playing area sizes and player number combinations were utilised (Little and Williams 2006; Little and Williams 2007). Furthermore, some studies have not reported the SSG format; including the duration of intervals and recovery intervals and the number of games (Sassi et al., 2004; Williams and Owen, 2007; Gabbett, 2008; Hill-Haas et al., 2008), providing little explanation for the exercise intensity achieved. Moreover, conditioning studies using SSGs have rarely reported SSG intensity in rugby union (Gamble, 2004), RL (Gabbett 2005a; 2005b; 2006a; 2006b), soccer (Reilly and White, 2004; Chamari et al., 2005) and volleyball (Gabbett 2006d, 2008); merely stating the physiological effects of the training programme (Table 2.6).

A study by Mallo and Navarro (2007) reported three intervals of five-minute 3v3 soccer SSGs interspersed with 10 minutes active recovery to be an appropriate training stimulus. Interestingly, the SSG intensity altered across three different 3v3 games, namely, ordinary football rules with goalkeepers (88% HRmax), a possession game with the aim of keeping possession as long as possible (91% HRmax), and a game with two outer players permitted to pass to a player from the team that they received a pass from (91% HRmax). The authors suggested that the first game obtained a lower intensity due to the inclusion of goalkeepers, as the players appeared to defensively organise their team in order to protect their goal (Mallo and Navarro, 2007). This study demonstrated that SSG rules can be manipulated in order to alter intensity and therefore the conditioning stimulus. Moreover, even though the SSGs in this study were longer in duration than the standard four minute SSG studies (Hoff et al., 2002; Aroso et al., 2004; Chamari et al., 2005; Impellizzeri et al., 2006, Rampinini et al., 2007a; Coutts et al., 2009; Kelly and Drust, 2009) and had an active recovery duration more than three times longer than the average three minutes used in previous SSG studies (Hoff et al., 2002; Aroso et al., 2004; Chamari et al., 2005; Impellizzeri et al., 2006; Rampinini et al., 2007a; Coutts et al., 2009), an appropriate intensity above 90% HRmax (Helgerud et al., 2007) was achieved in two of the three

SSGs. This may have been possible due to the good organisation of the SSGs with balls immediately replaced when out of play. Equally, Kelly and Drust (2009) found that two out of three four-minute 5v5 soccer SSGs with only two minutes of recovery between intervals elicited mean HR responses above 90% HRmax. These studies demonstrate that other interval and recovery durations can produce an appropriate training stimulus above 90% HRmax, specifically, five minute intervals and two minute recovery periods. Thus, further research into SSG interval and recovery duration is warranted.

There are some discrepancies between the reported SSG intensities that might be deemed appropriate for aerobic development, as some studies which have shown SSGs to obtain intensities below 90% HRmax to be an appropriate stimulus for developing $\dot{V}O_{2max}$ (Sassi et al., 2004; Jones and Drust, 2007; Hill-Haas et al., 2009a). Intensities above 85% HRmax would achieve anaerobic development and some aerobic development. However, it is problematic to compare the above SSG findings as the game rules and game format are often not reported and SSG organisation, delivery and discipline may differ, such as coach encouragement and replacing balls back into play promptly. Nonetheless, the main discrepancies reported are the game and recovery durations, which appear to differ from the suggested format of four-minute intervals and three minute active recovery durations as reported originally in the HIT literature (Hoff et al., 2002; Helgerud et al., 2001; Helgerud et al., 2007; Rampinini et al., 2007). Small-sided game durations of 10 and 15 minutes have been reported (Jones and Drust, 2007; Platt et al., 2001), therefore lowering the average game intensity. Likewise, recovery intervals of only 90 s have been reported (Aroso et al., 2004), possibly resulting in a higher average session intensity but a lower SSG interval intensity, which changes the dynamics of the session from the HIT intervals of four minutes.

Table 2.2: The intensity of SSGs in a HIT format

Reference	Sport	N	Age (y)	SSG manipulation	Findings
Platt et al. (2001)	Soccer	Not clear	10-12	3v3 in 30x20 yards, 5v5 in 40x30 yards, 15-minute games, recoveries not reported.	3v3 = 184 b·min ⁻¹ (estimated 88 % HRmax) 5v5 = 172 b·min ⁻¹ (estimated 82% HRmax)
Hoff et al. (2002)	Soccer	6 M	22.2 ± 3.3	5v5, 4-minute games, 3-minutes active recoveries	91.3% of HRmax and 84.5% of $\dot{V}O_{2max}$
Aroso et al. (2004)	Soccer	14	15-16	2v2 (90 s games), 3v3 (4-minute games), 4v4 (6-minute games), 90 s recoveries	2v2 = 84% HRmax, 8.1 mmol·l ⁻¹ BL, 16.2 Borg RPE 4v4 = 87% HRmax, 4.9 mmol·l ⁻¹ BL, 14.5 Borg RPE 6v6 = 84% HRmax, 2.6 mmol·l ⁻¹ BL, 13.3 Borg RPE
Sassi et al. (2004)	Soccer	Not reported	Not reported	4v4 and 8v8 (format not reported)	4v4 = 174-178 b·min ⁻¹ 8v8 = 160 b·min ⁻¹
Impellizzeri et al. (2006)	Soccer	15	17.2 ± 0.8	3v3 to 5v5 in 25x35 to 40x50 m, 4-minute games, 3-minute active recoveries	91.3% HRmax
Little and Williams (2006)	Soccer	23 M	22.8 ± 4.5	2v2 to 8v8 in 30x20 to 65x30 m, varying reps and durations	2v2 = 90.8% HRmax, 3v3 = 90.6% HRmax, 4v4 = 90.2% HRmax, 5v5 = 89.3% HRmax, 6v6 = 87.5% HRmax
Tessitore et al. (2006)	Soccer	9	21.7 ± 2.4	6v6 in 30x40 m and 50x40 m, 3 and 8-minute games, 15-minute passive recoveries	61% and 70% $\dot{V}O_{2max}$ for large and small areas (3 min games), 70% and 76% $\dot{V}O_{2max}$ for large and small areas (8 min games)
Jones and Drust (2007)	Soccer	8 M	7 ± 1	4v4 in 30x25 m, 8v8 in 60x40 m, 10-minute games	4v4 = 175 b·min ⁻¹ (83% HRmax) 8v8 = 168 b·min ⁻¹ (79% HRmax)

HRmax=maximal heart rate, b·min⁻¹= beats per minute, $\dot{V}O_{2max}$ =maximal oxygen uptake, RPE=rate of perceived exertion, BL=blood lactate

Table 2.2 continued: The intensity of SSGs in a HIT format

Reference	Sport	N	Age (y)	SSG manipulation	Findings
Little and Williams (2007)	Soccer	28	24 ± 5	2v2 to 8v8 in 30x20 to 65x30 m, 2-8 minute games and 1.5-2 minute recoveries	2v2 = 88.7% HRmax, 3v3 = 91.2% HRmax, 4v4 = 90.2% HRmax, 5v5 = 88.8% HRmax, 6v6 = 87.7% HRmax, 8v8 = 88.2% HRmax
Mallo and Navarro (2007)	Soccer	10 M	18.4 ± 0.6	3v3 in 33x20 m, 3 different rule variations, 5-minute games, 10-minute active recoveries	88-91% HRmax
Rampinini et al. (2007)	Soccer	20 M	24.5 ± 4.1	3v3 to 6v6 in 12x20 to 36x48 m, with and without coach encouragement, 4-minute games, 3-minute active recoveries	3v3 = 87.6-90.9% HRmax, BL=4.4-6.5 mmol·l ⁻¹ , 6.6-8.5 CR10 RPE 4v4 = 86.5-89.7% HRmax, BL=4.2-6.0 mmol·l ⁻¹ , 6.3-8.1 CR10 RPE 5v5 = 86.0-88.8% HRmax, BL= 3.9-5.8 mmol·l ⁻¹ , 5.9-7.5 CR10 RPE 6v6 = 83.8-87.0% HRmax, BL=3.4-4.8 mmol·l ⁻¹ , 4.8-7.3 CR10 RPE
Williams and Owen (2007)	Soccer	9	17 ± 1	1v1 to 5v5 in 15x20 to 25x30 m, format not reported	152 - 183 b.min ⁻¹
Gabbett (2008)	Volleyball	12 M&F	15.6 ± 0.1	SSGs, 5v5, format not reported	159 ± 3 b.min-1
Coutts et al. (2009)	Soccer	20 M	25 ± 5	3v3 to 6v6 in 12x20 to 46x48 m, 4-minute games, 3-minute recoveries	87.9% HRmax, 5.6 mmol·l ⁻¹ , 7.0 CR10 RPE

HRmax=maximal heart rate, b·min⁻¹= beats per minute, $\dot{V}O_{2max}$ =maximal oxygen uptake, RPE=rate of perceived exertion, BL=blood lactate

Table 2.2 continued: The intensity of SSGs in a HIT format

Reference	Sport	N	Age (y)	SSG manipulation	Findings
Duarte et al. (2009)	Futsal	8	25.9 ± 4.5	2v2, 3v3, 4v4 in 20x20 m, 4-minute games, 4-minute active recoveries	2v2 = 87.9% HRmax 3v3 = 86.8% HRmax 4v4 = 81.5% HRmax
Katis and Kellis (2009)	Soccer	34	13 ± 0.9	3v3 in 15x25 m, 6v6 in 30x40 m, 4-minute games, 3-minute active recoveries	3v3 = 87.6% HRmax 6v6 = 82.8% HRmax
Kelly and Drust (2009)	Soccer	8 M	16.2 ± 0.3	5v5 in 30x20, 40x30, 50x40 m, 4-minute games, 2-minute active recoveries	30x20 m = 91% HRmax 40x30 m = 90% HRmax 50x40 m = 89% HRmax
Casamichana and Castellano (2010)	Soccer	10 M	15.5 ± 0.5	5v5 in 32x23, 50x35, 62x44 m, 8-minute games, 5-minute passive recoveries	62x44 m = 88.9% HRmax, 6.7 CR10 50x35 m = 88.5% HRmax, 6.7 CR10 32x23 m = 86.0% HRmax, 5.7 CR10
Gabbett et al. (2010)	Rugby league	16 M	17.3 ± 0.9	8v8 in 40x40 m, 8-minute games, 3-minute recoveries	Onside games = 164 ± 2 b·min ⁻¹ Offside games = 175 ± 4 b·min ⁻¹
Foster et al. (2010)	Rugby league	22 M	12.6 ± 0.5 (U13) 15.5 ± 0.5 (U16)	4v4 and 6v6 in 15x25, 20x30, 25x35 m, 4-minute games, 3-minute active recoveries	U13: 88.1% HRmax in 4v4, 89.3% in 6v6 U16: 90.6% HRmax in 4v4, 86.2% in 6v6
Fanchini et al. (2011)	Soccer	19 M	24 ± 4	3v3 in 37x31 m, 2-, 4- and 6-minute games, 4-minutes active recoveries	2 minute games = 82.4% HRmax, 6.7 CR10 RPE 4 minute games = 85.9% HRmax, 6.8 CR10 RPE 6 minute games = 85.6% HRmax, 6.8 CR10 RPE

HRmax=maximal heart rate, b·min⁻¹= beats per minute, $\dot{V}O_{2max}$ =maximal oxygen uptake, RPE=rate of perceived exertion, BL=blood lactate

2.5.2 Factors affecting the physiological demands of small-sided games

It is important to be able to regulate SSG training intensity in order to achieve the physiological adaptations desired. Surprisingly, although coaches commonly modify the playing rules of SSGs to alter the physical and technical loads imposed on players (Hill-Haas et al., 2010), there has been very little investigation into the affects of common rule changes on these demands. Mallo and Nevarro (2007) carried out a series of five-minute soccer SSG as follows; SSG 1: 3v3 with the aim of keeping the ball in possession as much as possible; SSG 2: 3v3 with two neutral players outside pitch who could pass to a player from the team they received the ball from; SSG 3: 3v3 with goalkeepers and normal football rules. Total distance covered and mean HR were reported to be higher in SSGs 1 (747 ± 24 m and 173 ± 10 b \cdot min $^{-1}$, respectively) and 2 (749 ± 29 m and 173 ± 9 b \cdot min $^{-1}$, respectively) than SSG 3 (638 ± 34 m and 166 ± 11 b \cdot min $^{-1}$, respectively). The authors suggested that the lowered demands found in SSG 3 were due to the games incorporating goalkeepers, resulting in players organising their team in order to protect their goal and therefore obtaining less high-intensity running and more low-intensity activities.

In the same vein, Hill-Haas et al. (2010) determined the effects of changing player rules on soccer SSGs in elite youth players. A series of 24 minute SSGs were carried out across a 16-week period in which conditions were strategically applied as follows; SSG 1: a soccer offside rule was applied; SSG 2: same as SSG 1 plus all attacking players had to be in the front two zones for a goal to count; SSG 3: same as previous SSGs plus two neutral players outside the pitch had to receive a pass each prior to a goal being scored and SSG 4: same as previous SSGs plus one person from each team sprinted and jogged the width and length of the pitch, respectively. The rule change that required players to complete extra running (SSG 4) obtained the greatest time-motion demands with a greater amount of total distance covered, high intensity running and number of sprints than the other rule changes. However, no differences in the physiological (%HRmax and blood lactate) or perceptual (RPE, Borg, 1970) demands were reported, possibly due to players pacing themselves across the 24 minute duration SSGs.

Unsurprisingly, the intensity was lower than previously reported in SSG studies (81.2-84% HRmax) and the changes reported in altering format and conditions in other SSG studies could have been obtained due to the increased intensity as a result of the HIT format utilised. In contrast, SSG 2, which required all players to be in the front two thirds of the pitch for a goal to be allowed, increased %HRmax and blood lactate in small and large game formats, respectively. Thus, the authors suggested that technical rules related to goal scoring might influence players' motivation and therefore increase exercise intensity. However, 24 minute SSGs were utilised, making comparisons to HIT SSG formats problematic, and the study was conducted over a 16-week period in which players' responses could have been affected by changes in fitness levels. In addition, the high-intensity zone employed (running over 13 km·hr⁻¹) is considerably lower than high-intensity zones utilised in previous SSG studies (>18 km·hr⁻¹; Hill-Haas et al., 2008, 2009a, 2009c, Casamichana and Castellano, 2010). Furthermore, the changes in rules were applied in addition to the previous rule changes and not in isolation. Therefore, the affects of some of the rule changes remains undetermined, specifically, the offside rule which was applied to all SSGs.

A recent study has examined the technical and movement demands of onside and offside 8v8 RL SSGs in a 40x40 m playing area (Gabbett et al., 2010). A SSG session of two eight-minute SSGs separated by three minutes recovery was carried out twice across two sessions. The SSG rules were identical apart from an offside (forward and backward passes) and onside (backward passes only) rule. The offside SSGs obtained higher numbers of touches, passes and effective passes. In addition, through GPS analysis, the offside SSGs were found to elicit a greater total distance covered, distance covered in mild and moderate accelerations and distance covered in low, moderate and high velocity efforts. These findings demonstrate that SSG rules can be manipulated to increase the technical and physical demands and that the utilisation of offside SSGs may be more appropriate in increasing fitness and skills than onside SSGs. However, no analysis of HR was incorporated as a measure of individual work intensity common to the majority of SSG studies. Moreover, it would be interesting to establish if the

differences in demands between onside and offside SSGs are similar or differ further when the player number is reduced to a more appropriate number for aerobic conditioning, such as 3v3 or 4v4, as mentioned previously.

There has been great interest in determining the effects of altering SSG variables (Table 2.3); however, the majority of research is limited to soccer SSGs. In analysing player format in isolation, the general trend within SSG studies is that decreasing player number increases SSG intensity (Aroso et al., 2004; Sassi et al., 2004; Duarte et al., 2009). Sassi et al. (2004) found 4v4 games to elicit higher HR and blood lactate values than 8v8 SSGs ($178 \pm 7 \text{ b}\cdot\text{min}^{-1}$ and $6.4 \pm 2.7 \text{ mmol}\cdot\text{l}^{-1}$ and $174 \pm 7 \text{ b}\cdot\text{min}^{-1}$ and $6.2 \pm 1.4 \text{ mmol}\cdot\text{l}^{-1}$ in 4v4 SSGs with and without goalkeepers, respectively, compared to $160 \pm 3 \text{ b}\cdot\text{min}^{-1}$ and $3.3 \pm 1.2 \text{ mmol}\cdot\text{l}^{-1}$ in 8v8 SSGs). Interestingly, higher exercise intensities were achieved in 8v8 games when extra conditioning rules (pressing) were introduced ($175 \pm 4 \text{ b}\cdot\text{min}^{-1}$); again reflecting that rule manipulation is an important factor in regulating SSG intensity. However, SSGs with different rules were used in the 4v4 and 8v8 conditions making comparisons across the different playing number formats difficult and the playing area sizes and SSG durations were not stated. Aroso et al. (2004) analysed the effects of 2v2, 3v3 and 4v4 SSGs in a playing area size of 20x30 m. The following HR intensities were obtained in three SSG intervals of 1.5, 4 and 6 minutes with 1.5 minutes recovery durations carried out with 2v2 ($84 \pm 5\% \text{ HR}_{\text{max}}$), 3v3 ($87 \pm 3\% \text{ HR}_{\text{max}}$) and 4v4 ($79 \pm 6\% \text{ HR}_{\text{max}}$) SSGs, respectively. These results would suggest that the 3v3 SSG carried out for four minutes elicited the greatest HR response. However, it is not possible to justify this finding as inconsistent SSG durations and player numbers were utilised, and therefore the demands of altering player number or SSG duration in isolation were not identified. In contrast, blood lactate concentrations of 8.1 ± 2.7 , 4.9 ± 2.0 and $2.6 \pm 1.7 \text{ mmol}\cdot\text{l}^{-1}$ were reported for the 2v2, 3v3 and 4v4 SSGs, respectively. These observations would suggest that the 2v2 SSG carried out for 1.5 minutes was the most intense, although it is unclear when blood lactate concentration was measured. Duarte et al. (2009) examined the difference between four-minute 2v2, 3v3 and 4v4 futsal SSGs. Reducing player number was found to increase HR responses,

although the intensity achieved was below 90% HRmax in all conditions (87.9, 86.8, 81.5% HRmax in 2v2, 3v3 and 4v4 SSGs, respectively).

In determining the optimal player number for aerobic conditioning within soccer SSGs, Little and Williams (2006) found the following HR intensities elicited in 2v2 (90.8% HRmax), 3v3 (90.6% HRmax) and 4v4 SSGs (90.2% HRmax) whereas 5v5 and 6v6 SSGs achieved an intensity below 90% HRmax (89.3 and 87.5% HRmax, respectively), suggesting that there is a decrease in the physiological stimulus when player number rises above 4v4 within soccer SSGs. Likewise, Little and Williams (2007) again found 3v3 and 4v4 soccer SSGs to elicit HR values above 90% HRmax (91.2 ± 1.3 and $90.2 \pm 1.6\%$ HRmax, respectively) whereas 2v2, 5v5, 6v6 and 8v8 SSGs failed to reach this intensity ($<90\%$ HRmax). Equally, Rampinini et al. (2007) found only 3v3 soccer SSGs to elicit above 90% HRmax, with 4v4, 5v5 and 6v6 SSGs producing average exercise intensities below this value although the game repetitions, interval and recovery duration differed in each format, making a comparison across the player number formats problematic. An additional finding of Rampinini et al.'s (2007) study was that SSGs with coach encouragement elicited a higher average HR in all SSG formats than games without coach encouragement, which could reflect increased external motivation and competitiveness (Mazzetti et al., 2000; Coutts, 2004; Gentil and Bottaro, 2010).

A recent study determined the effects of over- and under-loading player number in elite youth soccer players (Hill-Haas et al., 2010). A series of 24 minute SSGs were carried out across a 16-week period in the following four formats; 3v4, 3v3 plus a floating player who could transition to the team with possession of the ball, 5v6, and 5v5 plus a floating player. The RPE score was found to be higher in 3v3 SSGs compared to 4v4 SSGs (16 ± 2 and 15 ± 2 , respectively), although no other differences were reported in time-motion (number of sprints, high intensity running efforts) or physiological characteristics (blood lactate and %HRmax). Removing the floating players from the analyses, temporary matched teams (3v3, 5v5) were found to elicit a greater total distance covered and RPE score than fixed overload teams (6

and 4 player teams) although no differences were reported in high-intensity running ($>13 \text{ km}\cdot\text{h}^{-1}$), %HRmax or blood lactate values. However, the pitch size changed for the small (3v3, 3v4) and large (5v5, 5v6) formats (37x28 and 47x35 m, respectively), maintaining the same pitch per player ratio and therefore not determining the effects of altering player number in isolation. Whilst these results suggest that the matched teams, who were effectively under-loaded by one player in comparison to their opposition, obtained the greatest SSG intensity, the players may have employed a pacing strategy due to the 24 minute SSG duration, as there were no other differences reported in other physiological and time-motion characteristics. Consequently, further research into the effects of over- and under- loading player number within SSGs is required.

Collectively, it is apparent from the SSG literature that reducing player number within soccer SSGs to 3v3 or possibly 4v4 seems to be the most consistent format in achieving above 90% HRmax, and is possibly therefore the most appropriate format for aerobic conditioning using SSGs within a HIT format. A possible explanation for the increase in exercise intensity with reducing player number in SSGs is a greater frequency of contact with the ball and overall individual involvement (Rampinini et al., 2007). Indeed, Katis and Kellis (2009) reported a greater frequency of technical action performed in 3v3 soccer SSGs compared to 6v6 SSGs (see section 2.6.3). Likewise, Jones and Drust (2007) found that reducing player number in soccer SSGs from 8v8 to 4v4 resulted in an increased number of individual contacts from 13 ± 7 to 36 ± 12 . However, despite players being classed as elite, it is difficult to compare this study with other SSG studies as the participants were very young (7 ± 1 years). Moreover, while the playing area size also increased simultaneously with player number (4v4 on a 30x25 m pitch and 8v8 on a 60x40 m pitch), specific positional formations were incorporated; namely, a diamond 1-2-1 formation in the 4v4 SSGs and a 1-3-2-2 in the 8v8 SSGs, which restricting players' workspace and role within the SSGs. It is therefore not surprising that no significant differences were reported in the HR responses to the 4v4 and 8v8 SSGs (83 and 79% HRmax in 4v4 and 8v8 SSGs, respectively). In addition, an increase in SSG intensity due to a

reduction in player number could be due to players having to work harder off the ball to create space (Katis and Kellis, 2009) and having more space in which to play. Thus, further research is required.

There are conflicting findings from the few studies which have analysed the effects of altering playing area size in isolation in soccer SSGs. Tessitore et al. (2006) reported 6v6 soccer SSGs elicited a larger intensity in a smaller playing area size (30x40 m; $70 \pm 13\%$ and $76 \pm 10\%$ estimated $\dot{V}O_{2max}$ in three and eight-minute SSGs, respectively) than a larger playing area size (50x40 m; $61 \pm 13\%$ and $70 \pm 11\%$ estimated $\dot{V}O_{2max}$ in three and eight-minute SSGs, respectively), which the authors suggested was likely to have resulted from greater man-to-man defending in the smaller size. This finding demonstrates that SSG rules can greatly influence the tactics and therefore the intensity achieved. Interestingly, Kelly and Drust (2009) found playing area size to have no effect on HR intensity within four minute soccer SSGs, as small (30x20 m), medium (40x30 m) and large (50x40 m) playing areas elicited average HR intensities of 91 ± 4 , 90 ± 4 and $89 \pm 2\%$ HRmax, respectively. However, goalkeepers were included in the 5v5 SSGs, which could have lowered the average SSG intensity, as it is unclear if they were included in the analyses. In contrast, Casamichana and Castellano (2010) found 8-minute 5v5 soccer SSGs with goalkeepers to elicit different demands when played on three different size playing areas, specifically, 62x44 m, 50x35 m and 32x23 m (large, medium and small areas, respectively). Regional soccer players (15.5 ± 0.5 years) were found to elicit a greater CR10 RPE score (6.7 ± 0.8), higher %HRmax ($88.9 \pm 3.9\%$ HRmax) and a greater total distance covered (999.6 ± 50.0 m) in the large playing area in comparison to the medium (CR10 RPE score = 6.7 ± 0.8 , %HRmax = $88.5 \pm 4.9\%$, total distance covered = 908.9 ± 30.6 m) and small playing areas (CR10 RPE score = 5.7 ± 1.0 , %HRmax = $86.0 \pm 5.8\%$, total distance covered = 695.5 ± 37.1 m). Together, the above studies demonstrate that there are contrasting findings in altering playing area size in isolation in soccer SSGs.

In recognising characteristics that might influence the intensity of SSGs, the studies of Rampinini et al. (2007) and Owen et al. (2004) reported that increasing the playing area size and decreasing player number simultaneously resulted in a higher work intensity in soccer SSGs. Rampinini et al. (2007) carried out four minute SSGs with three minutes of active recovery in 3v3, 4v4, 5v5 and 6v6 formats in varying playing area sizes from 12x20 to 36x48 m. A higher HR and blood lactate concentration was reported on the larger playing areas in comparison to the small and medium playing areas for all formats. Owen et al. (2004) analysed the physiological and technical demands of five three-minute SSGs with player format ranging from 1v1 to 5v5 across different sized playing areas (ranging from 5x10 to 35x40 m). Although it was unclear if statistical analyses had been conducted, a reduction in player number and an increase in playing area size were reported to increase exercise intensity.

A reduction in both player number and playing area size has been found to increase soccer SSG exercise intensity (Platt et al., 2001; Little and Williams, 2006; Little and Williams, 2007; Williams and Owen, 2007; Hill-Haas et al., 2009a; Katis and Kellis, 2009). However, it is difficult to compare the interaction effects in the above studies as the number of games, game durations and recovery durations often differ between studies (Little and Williams, 2006; Little and Williams, 2007). Moreover, the use of inconsistent playing area sizes (Owen et al., 2004; Rampinini et al., 2007; Katis and Kellis, 2009) or different playing area sizes being matched to different player number combinations in order to maintain a consistent pitch area per player (Jones and Drust, 2007; Hill-Hass et al., 2009a; Hill-Haas et al., 2010) does not allow for the effect of altering player number or playing area size to be examined in isolation (Impellizzeri et al., 2006).

Table 2.3: Factors affecting the physiological demands of SSGs

Reference	N	Age (y)	SSG manipulation	Findings
Platt et al. (2001)	Not reported	10-12	3v3 in 30x20 yards, 5v5 in 40x30 yards, 15-minute games. Recoveries not reported.	↓ number and area = ↑ HR
Aroso et al. (2004)	14	15-16	2v2 (90 s games), 3v3 (4-minute games), 4v4 (6-minute games), 90 s recoveries	↓ number = ↑ HR and blood lactate (although 2v2 > HR than 3v3)
Owen et al. (2004)	Not reported	17.5 ± 1.1	1v1 to 5v5 games in 5x10 to 35x40 m, 3-minute games, 12-minute active recoveries	↓ number and ↑ size = ↑ HR. ↑ number = ↑ total technical action, altering size had no effect on technical actions
Sassi et al. (2004)	Not reported	Not reported	4v4 and 8v8 (format not reported)	↓ number = ↑ HR
Little and Williams (2006)	23 M	22.8 ± 4.5	2v2 to 8v8 in 30x20 to 65x30 m, varying reps and durations	↓ number and area = ↑ HR
Tessitore et al. (2006)	9	21.7 ± 2.4	6v6 in 30x40 m, 6v6 in 50x40 m, 3-and 8-minute games, 15-minute recoveries	↓ area size = ↑ HR
Jones and Drust (2007)	8 M	7 ± 1	4v4 in 30x25 m, 8v8 in 60x40 m, 10-minute games, 2-minutes of passive recovery	↓ number and area = no differences in HR

HR = heart rate, CR10 RPE = CR10 ratings of perceived exertion, ↓ = increase, ↓ = decrease

Table 2.3 continued: Factors affecting the physiological demands of SSGs

Reference	N	Age (y)	SSG manipulation	Findings
Little and Williams (2007)	28	24 ± 5	2v2 to 8v8 in 30x20 to 65x30 m, 2- to 8-minute games	↓ number and area = ↑ HR and Borg RPE
Mallo and Navarro (2007)	10 M	18.4 ± 0.6	3v3 in 33x20 m, 3 different rule variations, 5-minute games, 10-minute active recoveries	Changing SSG rules affected SSG intensity
Rampinini et al. (2007)	20 M	24.5 ± 4.1	3v3 to 6v6 in 12x20 to 36x48 m, with and without coach encouragement, 4-minute games, 3-minute active recoveries	↓ number and ↑ playing area size = ↑ HR, blood lactate, CR10 RPE. Coach encouragement = ↑ HR, blood lactate, CR10 RPE
Williams and Owen (2007)	9	17 ± 1	1v1 to 5v5 in 15x20 to 25x30 m, (format not reported)	↓ number = ↑ HR
Duarte et al. (2009)	8	25.9 ± 4.5	2v2 to 4v4 in 20x20 m, 4-minute games, 4-minute active recoveries	↓ number = ↑ HR
Katis and Kellis (2009)	34	13 ± 0.9	3v3 in 15x25 m, 6v6, in 30x40 m, 4-minute games, 3-minute active recoveries	↓ number and area = ↑ HR

HR = heart rate, CR10 RPE = CR10 ratings of perceived exertion, ↑ = increase, ↓ = decrease

Table 2.3 continued: Factors affecting the physiological demands of SSGs

Reference	N	Age (y)	SSG manipulation	Findings
Kelly and Drust (2009)	8 M	18 ± 1	5v5 in 30x20 to 50x40 m, 4-minute games, 2-minute active recoveries	No difference in HR with altering area size
Casamichana and Castellano (2010)	10 M	15.5 ± 0.5	5v5 in 32x23, 50x35, 62x44 m, 8-minute games, 5-minute passive recoveries	↑ area size = ↑ HR
Foster et al. (2010)	22 M	12.6 ± 0.5 (U13) 15.5 ± 0.5 (U16)	4v4 and 6v6 in 15x25, 20x30, 25x35 m, 4-minute games, 3-minute active recoveries	No difference in altering area size No difference in player number in U13 games ↓ number ↑ HR in U16 games
Gabbett et al. (2010)	16 M	17.3 ± 0.9	8v8 in 40x40 m, 8-minute games, 3-minute recoveries, onside versus offside SSGs	Offside SSGs > HR than onside SSGs

HR = heart rate, CR10 RPE = CR10 ratings of perceived exertion, ↑ = increase, ↓ = decrease

2.5.3 Factors affecting the technical demands of SSGs

A well devised SSG training session enables concurrent training of technical skill and fitness through attention to game format and delivery. Studies have analysed the effects of altering player number (Aroso et al., 2004), playing area size (Tessitore et al., 2006; Barnes et al., 2008, Kelly and Drust, 2009) and both player number and playing area size (Platt et al., 2001; Owen et al., 2004; Jones and Drust, 2007; Hill-Hass et al., 2009a; Katis and Kellis, 2009) on the movement and technical demands in soccer SSGs (Table 2.4). However, there has been little attention to the technical analysis in RL SSGs. Furthermore, the majority of studies have carried out hand notation analysis (Platt et al., 2001; Owen et al., 2004; Jones and Drust, 2007; Katis and Kellis, 2009), with only recent studies using more elaborate analysis systems such as GPS (Barnes et al., 2008; Hill-Hass et al., 2008; Hill-Hass et al., 2009a; Gabbett et al., 2010; Casamichana and Castellano, 2010).

As mentioned in section 2.5.2, soccer SSG intensity has been shown to increase when player numbers are decreased. Using TMA, Aroso et al. (2004) have explained this pattern in soccer SSGs to be due to a reduction in the percentage of time spent walking and an increase in the time spent in moderate intensity exercise and sprinting. However, the TMA methods were not reported and their findings could possibly reflect differences in SSG format within their study as opposed to a significant difference in intensity, as different SSG interval and recovery durations were utilised with each playing number format. In examining the effect of altering playing area size in isolation on the movement demands of 5v5 soccer SSGs, Barnes et al. (2008) reported an increase in total distance covered and distance covered within a high intensity zone ($>19.8 \text{ km}\cdot\text{h}^{-1}$) in 5v5 soccer SSGs as playing area increased. However, the affects of manipulating SSG formats on distances covered within high intensity running warrants further research, as GPS analysis has been found to be less reliable within high intensity intermittent running ($>20 \text{ km}\cdot\text{h}^{-1}$; Coutts and Duffield, 2010).

Platt et al. (2001) analysed the effects on soccer SSG movement demands of the interaction of altering player number and playing area size and found that

a decrease in player number and an increase in playing area size resulted in an increase in high intensity movements and a decrease in low intensity movements (Platt et al., 2001), although these high and low intensities were not defined. However, Jones and Drust (2007) and Hill-Hass et al. (2009a) showed that reducing both player number and playing area size had no effect on low and high intensity movements, although the distance covered in backwards and sideways movements increased (140 ± 68 m and 107 ± 51 m in 4v4 and 8v8 SSGs, respectively; Jones and Drust, 2007) and mean duration and distances covered in sprints (>18 km·h⁻¹) reduced (Hill-Haas et al., 2009a) as player number decreased, possibly due to less absolute pitch space available for sprinting. However, as mentioned in section 2.5.2, it is difficult to compare Jones and Drust and Hill-Haas's studies to other SSG studies due to wide differences in player age, positional roles (Jones and Drust, 2007) and SSG interval and recovery duration (Hill-Haas et al., 2009a; Jones and Drust, 2007). Moreover, although Hill-Haas et al.'s study provides a comprehensive physiological and technical analysis of soccer SSGs through the use of GPS analysis, Jones and Drust's study employed a hand notation analysis, raising inter- and intra- observer reliability concerns due to the subjective method of producing time motion data.

Small-sided games have the ability to increase individual involvements and game situations due to the reduced playing area and number of participants utilised (Capranica et al., 2001). Therefore, good technical and tactical skills are required as well as cooperation with other players (Katis and Kellis, 2009). Whilst the majority of studies have analysed the frequency of technical actions within soccer SSGs (Owen et al., 2004; Tessitore et al., 2006; Mallo and Navarro et al., 2007; Jones and Drust, 2007; Kelly and Drust, 2009; Katis and Kellis, 2009), few have determined the success rate of these actions (Platt et al., 2001; Gabbett et al., 2010; Fanchini et al., 2011). In addition, few studies have examined the effects of manipulating player number in isolation on the frequency of technical actions performed (Duarte et al., 2009). Duarte et al. (2009) reported an increase in ball contacts and dribbles when player number was reduced in futsal SSGs

Within the few studies that have analysed the effects of altering playing area size in isolation, playing area size has been reported to have no effect on the number of technical actions performed (Tessitore et al., 2006; Kelly and Drust, 2009) suggesting that playing area size does not affect technical aspects of soccer SSGs. In an attempt to examine the effects on playing area size and player number in isolation, Owen et al. (2004) reported that a reduction in player number increased the number of individual technical actions, which was attributed to an increased number of passes, although only two players were analysed per match. Playing area size was reported to have no effect on the technical actions performed. However, it is unclear how these analyses were conducted as the statistical methods were not reported and the size of small, medium and large pitches altered for each playing number (1v1 to 5v5).

Studies that have analysed the interaction effects of altering both player number and playing area size on the technical demands of soccer SSGs have reported that a decrease in both player number and playing area size increased the number of individual ball contacts in soccer SSGs (Platt et al., 2001; Jones and Drust, 2007; Katis and Kellis, 2009). However, although it could be hypothesised that it is the changes in playing number that is affecting the technical actions performed, as playing area size has been found to have no effect on the frequency of technical actions performed (Owen et al., 2004; Tessitore et al., 2006; Kelly and Drust, 2009), further research is required to interpret if the changes in the technical demands of SSGs are due to changing the player number, playing area size or the interaction of both.

In the most comprehensive analysis of the technical demands of soccer SSGs to date, Katis and Kellis (2009) reported differences in the frequency of technical actions performed in 3v3 and 6v6 SSGs in 15x25 m and 30x40 m areas, respectively. As playing area size and player number were reduced simultaneously within the 3v3 SSGs, the majority of technical actions increased in comparison to the 6v6 SSGs, specifically, the number of short passes, kicks, tackles, dribbles and goals scored, suggesting reducing

players individual space within SSGs increases player cooperation through an increase in short passes and dribbles. However, the number of long passes and headers reduced within the 3v3 SSGs, possibly due to an increase in individual space in the 6v6 SSGs, permitting players to perform longer passes and therefore receive longer passes in the air. Moreover, the study stated that goalkeepers were included, although it was not specified if they were in addition or included in the player numbers. The addition of goalkeepers has been shown to alter SSG intensity, possibly due to players rearranging the defensive organisation of their team in order to protect their goal (Mallo and Navarro, 2007). In addition, the study was conducted with young amateur soccer players (13 ± 0.9 years), although the exact standard of play was not reported. It would be interesting to determine if these responses within four-minute SSGs are obtained with high-level junior and senior players.

Table 2.4: Factors affecting the movement and technical demands of SSGs

Reference	Sport	Method	Sample size	Age (y)	SSG manipulation	Findings
Platt et al. (2001)	Soccer	Hand notation	Not reported	10-12	3v3 in 30x20 yards, 5v5 in 40x30 yards, 15-minute games, recoveries not reported	↓ number and area = ↓ low intensity movements and ↑ high intensity movements and individual technical actions
Aroso et al. (2004)	Soccer	Not reported	14	15-16	2v2 (90 s games), 3v3 (4-minute games), 4v4 (6-minute games), 90 s recoveries	↑ number = ↑ walking, ↓ moderate exercise and sprinting
Owen et al. (2004)	Soccer	Hand notation	Not reported	17.5 ± 1.1	1v1 to 5v5 games in 5x10 to 35x40 m, 3-minute games, 12-minute active recoveries	↓ number = ↓ number of actions, ↑ number of individual actions. No difference in playing area size and actions
Tessitore et al. (2006)	Soccer	Hand notation	9	21.7 ± 2.4	6v6 in 30x40 m, 6v6 in 50x40 m, 3- and 8-minute games, 15-minute recoveries	No difference in technical actions per minute
Jones and Drust (2007)	Soccer	Hand notation	8 M	7 ± 1	4v4 in 30x25 m, 8v8 in 60x40 m, 10-minute games, 2-minute passive recoveries	No difference in TDC or DC in walking, jogging and sprinting, ↓ number and area = ↑ utility and individual ball contacts
Mallo and Nevarro (2007)	Soccer	Hand notation	10 M	18.4 ± 0.6	3v3 in 33x20 m, 3 different rule variations, 5-minute games, 10-minute active recoveries	Difference in DC in games with different rules
Barnes et al. (2008)	Soccer	GPS	5	16.9 ± 0.5	5v5 in 23x32 m, 27x37 m, 32x41 m, 4-minute games, 2-minute recoveries	↑ playing area = ↑ DC and DC in high intensity

TDC = total distance covered, DC = distance covered, ↑ = increased, ↓ = decreased

Table 2.4 continued: Factors affecting the movement and technical demands of SSGs

Reference	Sport	Method	Sample size	Age (y)	SSG manipulation	Findings
Duarte et al. (20009)	Futsal	Hand notation	8	25.9 ± 4.5	2v2, 3v3, 4v4 in 20x20 m, 4-minute games, 4-minute active recoveries	↓ number = ↑ in ball contacts and dribbles
Katis and Kellis (2009)	Soccer	Hand notation	34	13 ± 0.9	3v3 in 15x25 m, 6v6 in 30x40 m, 4-minute games, 3-minute active recoveries	3v3 = > number of short passes, kicks, tackles, dribbles, goals. 6v6 = > number of long passes and headers
Kelly and Drust (2009)	Soccer	Hand notation	8 M	16.2 ± 0.3	5v5 in 30x20, 40x30, 50x40 m, 4-minute games, 2-minute active recoveries	↑ playing area = ↑ number of tackles and shots. No difference in number of pass, receive, turn, dribble, header, interception
Gabbett et al. (2010)	Rugby league	GPS, hand notation	16 M	26 ± 4	8v8 onside and offside games in 40x30 m, 8-minute games, 3-minutes active recoveries	Offside games = >TDC, DC in mild and moderate accelerations, DC in low, moderate and high velocity efforts, number of touches, passes, effective passes
Casamichana and Castellano (2010)	Soccer	GPS	10 M	15.5 ± 0.5	5v5 in 32x23, 50x35, 62x44 m, 8-minute games, 5-minute passive recoveries	↑ playing area = ↑ TDC and DC in low, moderate and high intensities and sprint frequency

TDC = total distance covered, DC = distance covered, ↑ = increased, ↓ = decreased

2.5.4 Reliability of small-sided games

It is important to be able to consistently regulate training intensity in order to achieve the physiological adaptations desired. Ultimately, reliable SSGs would allow coaches to be confident in their ability to provide a consistent aerobic training stimulus and therefore permit a conditioning programme with controlled progressive overload. Traditional methods of aerobic conditioning for team sports have incorporated mainly running exercises over a fixed distance or duration, in which exercise intensity is relatively easy to monitor and control. Conversely, SSGs are intermittent and regulated more by the previously undetermined patterns of activity within the game, and hence it is more difficult to control the exercise intensity. Although there has been an interest in recent SSG research, few studies have determined the reliability of SSGs (Little and Williams, 2006; Tessitore et al., 2006; Little and Williams, 2007; Rampinini et al., 2007; Hill-Haas et al., 2008).

Tessitore et al. (2006) found 6v6 soccer SSGs to be reliable after finding no differences in the test-retest frequency distributions of HRs. However, this conclusion was based on analysis of variance (ANOVA) analysis and no reliability statistics were carried out. Little and Williams (2006) assessed the inter-subject variability and intra-subject repeatability of intensity within soccer SSGs. Twenty three professional players participated in SSGs ranging from 2v2 to 8v8 with varying playing area sizes, repetitions and durations. Small differences in HR intensity were reported between players in each of the SSGs (CV less than 3%). Ratio LoA of 1.8-3.8% were reported, which the authors concluded showed 'good' reliability, with the poorest test-test reliability (8v8) showing an error limit of $\pm 6 \text{ b}\cdot\text{min}^{-1}$. Interestingly, 2v2, 3v3, 4v4 and 6v6 SSGs elicited an exercise intensity between the suggested intensity of 90-95% HRmax, whereas 8v8 SSGs were below this intensity, further demonstrating the importance of player number as a factor for controlling the intensity of SSGs. A subsequent study, conducted by the same author, reported 'good' repeatability in soccer SSGs of similar player formats (CV of 1.3-2.2% and 5.1-9.9% for HR and Borg RPE, respectively).

Similar findings by Hill-Haas et al. (2008) have also indicated that soccer SSGs provide a reliable aerobic conditioning stimulus in adolescent soccer players. Small-sided games were carried out with different player numbers and playing area sizes in a randomised test-retest design. Interestingly, the duration of the SSGs were also compared in an interval (4 x 6 minute intervals) and continuous format (24 minutes). All SSG formats demonstrated good reliability with a technical error of <5% in mean HR responses, total distance covered and the percentage of total time moving at 0-6.9 km·h⁻¹. This measure of agreement has been used previously in assessment of rugby game actions (Hughes et al., 2002; Eaves et al., 2003; Eaves and Broad, 2007). Furthermore, these small variations in performance parameters were consistent across games involving different player numbers, although variability increased in all number formats when sprinting, possibly due to the GPS sampling rate of only 1 Hz, coupled with the short duration of sprints. Whilst the aforementioned study is the only research to assess the repeatability of SSG movement demands as well as physiological demands to date, reliability analyses were determined through technical error calculations, whereas Atkinson and Nevill (1998) have suggested the LoA statistic should be utilised in determining reliability.

Rampinini et al. (2007) assessed reliability and inter-participant variability of %HRmax, blood lactate concentration and RPE within soccer SSGs via LoA and CV. A series of 3 x four-minute SSGs were carried out with three minutes active recovery between games in which the player numbers, playing area sizes and level of verbal encouragement were altered. Overall, the reliability statistics reflect moderate to poor reliability of the SSGs with the smallest inter-participant variability in measurement methods being HR, and then RPE, followed by blood lactate concentration. Consequently, these observations might suggest that HR is the most appropriate method for monitoring intensity within SSGs. Furthermore, SSGs with coach encouragement showed greater reliability than SSGs without coach encouragement (CV ranged from 2.2 to 4.8% HRmax and 3.0 to 5.4% HRmax respectively), possibly due to the higher intensity achieved in the

SSGs with coach encouragement. Likewise, SGSs became more reliable at higher exercise intensities when player number was reduced.

Whilst the majority of soccer SSGs have reported SSGs to be repeatable on a test-retest basis (Little and Williams, 2006; Tessitore et al., 2006; Little and Williams, 2007, Hill-Haas et al., 2008) conflicting results have also been produced (Rampinini et al., 2007), questioning the reliability of soccer SSGs. Therefore, further studies are required to permit SSGs to be presented as a viable alternative for traditional conditioning methods of continuous and linear interval running. Furthermore, to date, there has been no investigation into the reliability of RL-specific SSGs, and therefore it is unclear if such games produce consistent stimuli to elicit aerobic adaptations on a test-retest basis. Therefore, findings from SSG reliability studies (see Table 2.5) must be interpreted with caution.

Table 2.5: Reliability of soccer SSGs

Reference	Sample size	Age (yrs)	SSG manipulation	Findings
Tessitore et al. (2006)	9	21.7 ± 2.4	6v6 in 30x40 m, 6v6 in 50x40 m, 3- and 8-minute games, 15-minute recoveries	Good reliability (No sig difference in HR between test-retest sessions; ANOVA)
Little and Williams (2006)	23	22.8 ± 4.5	2v2 to 8v8 in 30x20 to 70x45 m, 2-8 minute games and 1.5-2 minute recoveries	Good reliability (CV < 3% for all games, ratio LoA showed 95% error limits of 1.8-3.8%)
Little and Williams (2007)	28	24 ± 5	2v2 to 8v8 in 30x20 to 70x45 m, 2-8 minute games and 1.5-2 minute recoveries	Good reliability (HR CV = 1.3-2.2%, Borg RPE = CV 5.1-9.9%)
Rampinini et al. (2007)	20 M	24.5 ± 4.1	3v3 to 6v6 in 12x20 to 36x48 m, with and without CE, 4-minute games, 3-minute active recoveries	Poor to moderate reliability (SSGs with CE had > LoA and CV than games without CE. Games were more producible when intensity was high)
Hill-Haas et al. (2008)	16 M	16.2	2v2 to 6v6 in 28x21 to 49x37 m, 6-minute games, 1.5-minute passive recoveries	Good reliability (%HRmax TE% scores <5%). Small variability in time motion data (TE< 11%) although ↑ variability at higher movement speeds

HR = heart rate, RPE = rating of perceived exertion, %HRmax, = percentage of maximal heart rate, CV = coefficients of variation, LoA = limits of agreement, TE = typical error, TE% = typical error as a percentage of mean, ANOVA = analysis of variance

2.5.5 Small-sided game conditioning programmes

Small sided games have been introduced as part of specific conditioning programmes in RL (Gabbett, 2005a; 2005b; 2006a), soccer (Reilly and White, 2004; Chamari et al., 2005; Hill-Haas 2009b), volleyball (Gabbett et al., 2006d; Gabbett, 2008) and as a sole conditioning method alongside low intensity technical training in soccer (Impellizzeri et al., 2006; Rampinini et al., 2007), rugby union (Gamble, 2004) and RL (Gabbett, 2006b) (Table 2.6). Conditioning programmes utilising SSGs have shown no change in $\dot{V}O_{2\max}$ during pre-season (Hill-Haas et al., 2009b), in-season (Reilly and White, 2004) and towards the end of the season (Gabbett, 2005b). In contrast, increases in $\dot{V}O_{2\max}$ during both pre-season (Gabbett, 2005a; 2005b; 2006a; 2008) and mid-season (Chamari et al., 2005) training phases have been reported. However, it is uncertain whether the physiological changes were achieved through SSG conditioning alone or in combination with other RL-specific training methods such as skill, speed, power and agility training. In addition, it is unclear whether SSGs would have had an adverse effect on physiological parameters other than aerobic fitness if players did not participate in other specific types of training. Studies incorporating SSGs as their sole conditioning method have reported enhanced aerobic performance pre-season (Gamble, 2004; Impellizzeri et al., 2006) and during the competitive phase of the season (Gabbett, 2006b) (Table 2.6). However, whilst Impellizzeri et al. (2006) compared a SSG conditioning programme to a HIT running programme of the same format, other studies have either compared SSG training to traditional rugby training involving speed, power, agility and aerobic fitness common to RL training (Gabbett, 2006b) or have employed no control conditions (Gamble, 2004).

Gabbett (2004) monitored physical fitness in sub-elite RL players across three consecutive pre-seasons of periodised skills training and conditioning. Players carried out a game specific training programme twice per week for three months. $\dot{V}O_{2\max}$ values progressively improved throughout the three pre-seasons (2001, 7.7%; 2002, 11.8%; 2003, 15.6%) with each pre-season period inducing a significant increase in $\dot{V}O_{2\max}$ ($P<0.05$). However, the

greater changes in aerobic fitness over the three consecutive pre-seasons could possibly have occurred due to players having lower pre-training $\dot{V}O_{2\max}$ values in the 2002 and 2003 pre-season periods (Gabbett, 2004). This study focused on the injury rates and training loads and did not specify the type of training, making comparisons with conditioning using SSGs alone or within conditioning programmes difficult. The author noted it was difficult to train all physiological parameters effectively and develop skill in just two weekly training sessions of 90 minutes duration, further supporting the need for efficient sport-specific training.

Subsequent conditioning studies were conducted in which amateur senior RL players (Gabbett, 2005a), sub-elite (Gabbett, 2006a), non-elite junior RL players (17-19 years) (Gabbett, 2005b) and sub-elite junior RL players (16-17 years) (Gabbett, 2006a) undertook a progressively overloaded programme, involving skill, speed, muscular power, agility, and endurance training twice per week across a competitive season (nine months) (Gabbett, 2005a; 2005b) and in a 14 week pre-season training programme (Gabbett, 2006a). Players carried out a periodised, game specific programme which incorporated SSGs predominately alongside training of specific skills, speed, muscular power and agility. As a result, the combined SSG and traditional conditioning programmes significantly increased estimated $\dot{V}O_{2\max}$, muscular power and agility ($P<0.05$) in the pre-season training programmes (Gabbett, 2005a; 2005b; 2006a). Interestingly, towards the end of the season, there was a reduction in aerobic fitness in senior players when match loads and injury rates were at their highest and training loads at the lowest (Gabbett, 2005a), whereas junior players were able to maintain the increases in aerobic fitness, possibly due to the converse; lower match loads and injury rates. The finding of increased injury towards the end of the senior season would support the use of SSG conditioning mid-season, as a low volume, HIT training method (Gabbett, 2005a). Thus, further investigation into the effects of SSG conditioning mid-season and towards the end of the season is required in comparison to other aerobic training methods during these periods.

A nine week pre-season conditioning programme was carried out in senior professional rugby union players solely using SSGs as the conditioning method until the later stages where additional low intensity tactical sessions were introduced in preparation for competition (Gamble, 2004). The effectiveness of the SSG training programme was monitored each week by the completion of a standardised interval work bout, consisting of four two-minute stages in which shuttles were completed at increasing intensity each stage. However, the parameters used to monitor this test (%HRmax and %HRrecovery) are questionable, as %HRmax was derived from the highest HR achieved in the previous 12 months of training or within the SSGs in their current study, with no completion of a maximal exertion test. In addition, resting HR, from which HR reserve was calculated as the difference between HRmax and resting HR, was taken on arrival at training on conditioning days and not in a true rested state. Furthermore, there was no inclusion of a control group to account for any learning effect in completing the weekly interval bout test. The SSG training programme resulted in a significant decrease in %HRmax at the end of completion of the standardised interval work bout and a significant difference in %HR recovery score post training ($P<0.01$), suggesting that SSGs might provide an effective pre-season conditioning method.

Whilst the above study is one of the few that has determined the effects of conditioning using SSGs alone, the SSGs were not specific to the given sport (rugby union) and the format of the SSGs, including work to rest ratios, the number of training sessions per week and SSG intensity, were not reported, making replication of the training programme and comparison to SSG research difficult. A later study in soccer by Rampinini et al. (2007) also determined the effectiveness of a 10-month training programme in amateur soccer players solely using SSGs as their physical conditioning, alongside weekly matches and skills training. Four-minute SSGs interspersed with three minutes of active recovery were carried out two times per week across a competitive season. The training programme resulted in a significant increase in aerobic fitness with a 44.3% and 7.4% increase in the total

distance covered in the Yo-Yo endurance test and the intermittent recovery test, respectively.

Two studies have examined the effects of traditional team sports training methods and SSG training in soccer (Hill-Haas et al., 2009b) and RL (Gabbett, 2006b). Both studies compared traditional training methods of high intensity running, repeated sprints and agility work, whereas the SSGs were specific to soccer (Hill-Haas et al., 2009b) and team sports (Gabbett, 2006b). Thus, the latter games did not provide a true reflection of the demands of RL, but movement demands more general to team sports. Both studies found SSG conditioning to elicit similar training intensities and therefore concluded that both training methods are equally effective in developing aerobic fitness. However, whilst Gabbett (2006b) reported a 4.7% increase in $\dot{V}O_{2max}$ within the SSG conditioning group, Hill-Haas et al. (2009b) found no difference in $\dot{V}O_{2max}$, although the distance covered within the YoYo endurance test increased by 14.6%. The authors noted that the majority of SSGs used large format games (5v5 to 7v7), which they suggested may have resulted in the majority of time spent below 80% HRmax and ultimately obtaining the same intensity as the traditional training. Moreover, the SSG durations ranged from 6 to 13 minutes, with the majority of games played for 11 minutes, which is considerably longer than the suggested four-minute intervals (Helgerud et al., 2001; Helgerud et al., 2007). Interestingly, Gabbett (2006b) also reported greater improvements in muscular power and speed in the SSG conditioning programme, whereas muscular power actually decreased following the traditional running programme, suggesting that SSGs are an effective training method without having any adverse effects on other physiological parameters. Furthermore, Gabbett's (2006b) study is one of the few to indirectly assess skill development within the training programmes via a win:loss ratio of matches, in which both the traditional and SSG training groups had a 75% ratio, both winning six out of eight games (Gabbett, 2006b). However, these preliminary statistics were derived from matches played within the nine week training programmes. A more detailed technical match analysis including skill frequency counts or movement demands

before and after the training programmes would have provided a greater insight into any improvements in playing performance.

Table 2.6: Team sport SSG conditioning programmes

Reference	Sport	Sample size	Age	Season	Training Intervention	Findings
Gamble (2004)	Rugby union	35 M	27.6 ± 4.2	Pre-season	9 weeks, SSGs, volume and SSG format not reported	%HRmax** and %HRrecovery** ↓ at end of performance test
Reilly and White (2004)	Soccer	~9	18.2 ± 1.35	Competitive	5v5, 6 x 4-minutes, with 3-minute active recoveries at 50-60% HRmax, 2 x week, for 6 weeks	No change in estimated $\dot{V}O_{2max}$, muscular power, agility, anaerobic capacity or football skills
Chamari et al. (2005)	Soccer	18 M	14 ± 0.4	Mid-season	2 x week: 1 x Hoff test and 1 x SSG, 4 x 4 minute at 90-95% HRmax, 3-minute active recoveries at 60-70% HRmax, 8 weeks	$\dot{V}O_{2max}$ ↑ 7.5%*, DC in Hoff test ↑ 9.6%*
Gabbett (2005a)	Rugby league	52	18+	1 season	Skills, speed, agility training and SSG, 2 x week, for season, SSG format not reported	Estimated $\dot{V}O_{2max}$ * and muscular power* ↑ early season, estimated $\dot{V}O_{2max}$ * and muscular power* ↓ end season
Gabbett (2005b)	Rugby league	36	17.9 ± 0.4	1 season	Skills, speed, agility training and SSG, 2 x week, for season, SSG format not reported	Estimated $\dot{V}O_{2max}$ * , muscular power* and agility* ↑ early season and maintained through competitive season
Gabbett (2006a)	Rugby league	36	16.9 (CI 16.7-17.1)	Pre-season	SSGs, sprint training, skills training, 2 x week, for 14 weeks, SSG format not reported	$\dot{V}O_{2max}$ ↑ 8%*, muscular power ↑ 7.2%*, agility ↑ 17.7%*, no difference in speed
		41	25.5 (CI 23.6-27.3)	Pre-season	SSGs, sprint training, skills training, 2 x week, for 14 weeks	$\dot{V}O_{2max}$ ↑ 4.9%*, muscular power ↑ 4.5%*, Agility ↑ 16.3%*, no difference in speed
Gabbett (2006b)	Rugby league	32	22.1 ± 0.9	In-season	SSGs, 2 x week, for 9 weeks, SSG format not reported	10, 20 and 40 m speed ↓ 5.2%*, 3.2%* and 3%* respectively, muscular power ↑ 4.7%*, estimated $\dot{V}O_{2max}$ ↑ 4.7%*, no difference in agility

* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$, ↑ = increase, ↓ = decrease, HRmax = maximal heart rate, %HRmax = percentage of maximal heart rate, %HR recovery = % heart rate recovery score, $\dot{V}O_{2max}$ = maximal oxygen uptake, YoYo End = soccer specific endurance test, Ekblom = soccer specific endurance test

Table 2.6 continued: Team sport SSG conditioning programmes

Reference	Sport	Sample size	Age	Season	Training Intervention	Findings
Gabbett et al. (2006d)	Volleyball	26	15.5 ± 0.2	Not reported	Technical skills and SSGs, 3 x week, for 8 weeks, SSG format not reported	Volleyball skills ↑*, speed* and agility* ↑, no difference in estimated $\dot{V}O_{2max}$, muscular power or skinfold thickness
Impellizzeri et al. (2006)	Soccer	14	17.2 ± 0.8	Pre-season	SSGs, 4 x 4 minute games at 90-95% HRmax, 3-minute active recoveries at 70% HRmax = normal training. 2 x week, 4 weeks	$\dot{V}O_{2max}$ ↑ 6.6%*, VO_2 at LT ↑ 9.7%*, Ekblom time ↓ 12.2%*
		15	17.2 ± 0.9	Pre-season	SSGs, 4 x 4 minute games at 90-95% HRmax, 3-minute active recoveries at 70% HRmax = normal training. 2 x week, 4 weeks	No difference in $\dot{V}O_{2max}$, $\dot{V}O_2$ at LT ↑ 5%, Ekblom time ↓ 2.4%
Rampinini et al. (2007)	Soccer	20 M	24.5 ± 4.1	1 season	SSGs, 4-minute games, 3-minute active recoveries, 2-3 x week, 1 season	Yo Yo IRT ↑ 7.4%**, Yo Yo endurance test ↑ 44.3%***
Gabbett (2008)	Volleyball	12 M&F	15.6 ± 0.1	Not reported	SSGs, 3 x week = normal training, 12 weeks, format not reported	Estimated $\dot{V}O_{2max}$ ↑ 6.9%*, muscular power ↑ 7.1%*, speed ↑ 3%* and agility ↑ 10.4%*. Performance ↑ (serving ↑ 12.9%*, spike technique ↑ 3%*)
Hill-Haas et al. (2009b)	Soccer	10	14.6 ± 0.9	Pre-Season	SSGs, 2 x week = normal training, 7 weeks, SSG format not reported	No change in $\dot{V}O_{2max}$ or MSFT, Yo Yo End ↑ 14.6%*, no difference in sprint performance

* = $P < 0.05$, ** = $P < 0.01$, *** = $P < 0.001$, ↑ = increase, ↓ = decrease, HRmax = maximal heart rate, %HRmax = percentage of maximal heart rate, %HR recovery = % heart rate recovery score, $\dot{V}O_{2max}$ = maximal oxygen uptake, Yo Yo End = soccer specific endurance test, Ekblom = soccer specific endurance test

2.6 Conclusions

Rugby league is a high intensity, intermittent sport and consequently, the aerobic and anaerobic demands during competition are relatively high. In addition, RL players require high levels of aerobic fitness to be able to repeatedly perform high intensity movements, as aerobic fitness has been shown to enhance recovery from high-intensity efforts.

Traditional aerobic conditioning methods, such as continuous steady-state intensity training, have been criticised within conditioning programmes of team sports players due to being non-specific, time consuming and less motivating than more recent aerobic conditioning methods. However, in recent years, SSGs have emerged as a multi-component training method which enables fitness, technical and tactical elements to be trained simultaneously. Whilst generic in their function, SSGs can be designed to incorporate sport-specific principles in order to accommodate the rules, movement patterns and physical demands of a particular sport. In adopting this method, coaches are being persuaded that SSGs can be conducted at intensities sufficient to enable increases in aerobic fitness, while also providing a greater psychological stimulus than traditional conditioning methods and allowing decision making and problem solving through creating a 'learning through games' environment.

A commonly adopted format of four-minute intervals with three minutes active recovery has been found to be a suitable framework for obtaining work intensities above 90% HRmax in soccer SSGs. However, it is unclear if RL specific SSGs achieve similar intensities to those observed in other sports, and if the manipulation of SSG intensity can be achieved via altering playing rules, interval duration, player number, playing area size and the use of coach encouragement. Furthermore, although the technical demands of soccer SSGs seem well established, there has been no investigation into the technical demands of RL SSGs. Finally, it is important to be able to regulate training intensity in order to achieve the physiological adaptations desired. Although soccer SSGs have been found to be reliable, it is unclear if RL SSGs produce consistent stimuli (to elicit aerobic adaptations) on a test-

retest basis. Thus, determining the factors which affect the physiological and technical demands of RL SSGs, and the repeatability of these demands, will further RL coaches knowledge and practice of conditioning players in preparation for competition.

Chapter 3

Heart rate responses to small-sided games among high level junior rugby league players

The contents of this chapter form the basis of the following presentations and publications:

Publications:

Foster, C. (2009). Benefits of small-sided games. The Think Coaching E-Link. 35.

Foster, C. Twist, C. Lamb, K. Nicholas, C. (2010). Heart rate responses to small-sided games among elite junior rugby league players. *Journal of Strength and Conditioning Research*, 24, 906-911.

Presentations:

Foster, C. Twist, C. Lamb, K. Nicholas, C. (2007). An analysis of the heart rate responses to altering playing area size in rugby small-sided games. *12th Annual Congress of the European College of Sport Science*, Jyväskylä, Finland.

Foster, C. Sykes, D. Twist, C. Nicholas, C. Lamb, K. (2007). The heart rate responses during small-sided rugby league games. *British Association of Sport and Exercise Sciences Conference*, Bath University, UK.

Foster, C. Twist, C. Lamb, K. Nicholas, C. (2008). The heart rate responses and reproducibility of small-sided rugby league games. *13th Annual Congress of the European College of Sport Science*, Estoril, Portugal.

Foster, C. (2009). Factors to consider in the application of small-sided games for aerobic conditioning. *RFL Sport Science, Medicine and Performance Conference*. Leeds, UK.

3.1 Abstract

This study investigated the influences of player number and playing area size on the heart rate (HR) responses elicited by junior male rugby league (RL) players during small-sided games (SSGs). Twenty-two players from a professional club (mean age: 14.5 ± 1.5 yr; stature: 172.5 ± 11.4 cm; body mass: 67.8 ± 15.1 kg; $\dot{V}O_2$ peak: 53.3 ± 5.6 ml·kg⁻¹·min⁻¹; HRmax: 198 ± 7.8 b·min⁻¹) participated in two repeated trials of six four-minute conditioned SSGs over a two-week period. The SSGs varied by playing area size; 15x25 m, 20x30 m, and 25x35 m, and player number; 4v4 and 6v6. HRs were recorded continuously in each game and expressed as age-related (U13 and U16) means and percent of maximum (%HRmax). Analysis revealed non-significant ($P > 0.05$) effects of trials and playing area size on HRs, but a significant effect of player number in the U16 age group only ($P < 0.001$), with HRs being higher in the 4v4 (90.6% HRmax) than the 6v6 SSGs (86.2% HRmax). The HR responses were found to be repeatable in all SSG conditions (within $\pm 1.9\%$ HRmax) apart from the small 6v6 condition in the older players. The findings demonstrate that these SSGs generate physiological responses suitable for aerobic conditioning that, whilst unaffected by the size of the area used, are sensitive to the player number. Accordingly, among such players it is advisable that coaches employ 4v4 SSGs to achieve an appropriate and consistent aerobic conditioning stimulus.

3.2 Introduction

Rugby league is a contact team sport and is intermittent in nature, with periods of high intensity activity (running, tackling) and low intensity recovery (walking, jogging and standing). Competitive play has been shown to generate HRs equating to $84.3 \pm 4.8\%$ (Coutts et al., 2003) and $86.7 \pm 4.4\%$ (Estell et al., 1996) of maximal values. Rugby league can therefore be assumed to place a significant demand upon aerobic metabolism and duly requires high levels of aerobic fitness (Gabbett, 2005d; Gabbett et al., 2008).

To produce efficient training sessions, coaches of sports teams seek multiple component training methods to enable fitness, technical and tactical elements to be trained simultaneously. In recent years, SSGs have emerged as one such method, which, whilst generic in their function can be designed to adopt sport-specific principles to accommodate the rules, movement patterns and physical demands of a particular sport. In adopting this method, coaches are being persuaded that SSGs can be conducted at intensities sufficient to enable aerobic adaptations and allow transfer of skill from a pressurised training environment to a competitive environment. To achieve aerobic conditioning through SSGs, a HIT format has been adopted in soccer SSGs (Hoff et al., 2002; Aroso et al., 2004; Chamari et al., 2005; Impellizzeri et al., 2006; Little and Williams, 2006; Little and Williams, 2007; Mallo and Navarro, 2007; Rampinini et al., 2007; Coutts et al., 2009; Katis and Kellis, 2009; Kelly and Drust, 2009; Casamichana and Castellano, 2010; Fanchini et al., 2011). The majority of soccer SSG studies have adopted a framework of four-minute SSGs at 90-95% of maximal heart rate (HR_{max}) with three minutes of active recovery between games at ~70% HR_{max} (Hoff et al., 2002; Chamari et al., 2005; Impellizzeri et al., 2006; Rampinini et al., 2007; Coutts et al., 2009; Katis and Kellis, 2009). This format follows a HIT format for aerobic conditioning which has been shown to increase maximal oxygen uptake ($\dot{V}O_{2\max}$) (Helgerud et al., 2001; Helgerud et al., 2007) while simultaneously providing an ecologically valid training method (Hoff et al.,

2002) and a more motivating training stimulus than traditional aerobic conditioning methods (Impellizzeri et al., 2006).

Previous studies have found that SSG exercise intensity can be manipulated by altering playing area size and player number. In analysing player format in isolation, the general trend within SSG studies is that decreasing player number increases SSG intensity (Platt et al., 2001; Aroso et al., 2004; Sassi et al., 2004). Sassi et al. (2004) found 4v4 games to elicit higher HR and blood lactate values than 8v8 SSGs ($178 \pm 7 \text{ b} \cdot \text{min}^{-1}$ and $6.4 \pm 2.7 \text{ mmol} \cdot \text{l}^{-1}$ and $174 \pm 7 \text{ b} \cdot \text{min}^{-1}$ and $6.2 \pm 1.4 \text{ mmol} \cdot \text{l}^{-1}$ in 4v4 SSGs with and without goalkeepers, respectively, compared to $160 \pm 3 \text{ b} \cdot \text{min}^{-1}$ and $3.3 \pm 1.2 \text{ mmol} \cdot \text{l}^{-1}$ in 8v8 SSGs). However, SSGs with different rules were used in the 4v4 and 8v8 conditions, and the playing area sizes and SSG durations were not stated, making comparisons across the different playing number conditions difficult. In addition, Aroso et al. (2004) reported 2v2, 3v3 and 4v4 soccer SSGs in a playing area size of 20x30 m obtained $84 \pm 5\%$, $87 \pm 3\%$ and $79 \pm 6\%$ HRmax, respectively. These results would suggest that the 3v3 SSG carried out for four-minutes elicited the greatest HR response. However, it is not possible to justify this finding as different SSG durations were utilised for each player number format. In determining the optimal player number for aerobic conditioning within soccer SSGs, Little and Williams (2006) found 2v2, 3v3 and 4v4 soccer SSGs elicited an intensity above 90% HRmax whereas 5v5 and 6v6 SSGs achieved an intensity below 90% HRmax, suggesting that there is a decrease in the physiological stimulus when player number rises above 4v4 in soccer SSGs. Likewise, Little and Williams (2007) again found 3v3 and 4v4 soccer SSGs to elicit HR values above 90% HRmax (91.2 ± 1.3 and $90.2 \pm 1.6\%$ HRmax, respectively) whereas 2v2, 5v5, 6v6 and 8v8 SSGs were unable to reach this intensity ($<90\%$ HRmax). Equally, Rampinini et al. (2007) found only 3v3 soccer SSGs to elicit above 90% HRmax, with 4v4, 5v5 and 6v6 SSGs producing average exercise intensities below this value.

There are conflicting findings from the few studies which have analysed the effects of altering playing area size in isolation in soccer SSGs. Tessitore et

al. (2006) reported 6v6 soccer SSGs elicited a greater intensity in a smaller playing area size (30x40 m; $70 \pm 13\%$ and $76 \pm 10\%$ estimated $\dot{V}O_{2\max}$ in three and eight-minute SSGs, respectively) than a larger playing area size (50x40 m; $61 \pm 13\%$ and $70 \pm 11\%$ estimated $\dot{V}O_{2\max}$ in three and eight-minute SSGs, respectively), which the authors suggested was likely to have resulted from greater man-to-man defending in the smaller size. Interestingly, Kelly and Drust (2009) found playing area size to have no effect on HR intensity within four-minute soccer SSGs, as small (30x20 m), medium (40x30 m) and large (50x40 m) playing areas elicited average HR intensities of 91 ± 4 , 90 ± 4 and $89 \pm 2\%$ HRmax, respectively. In contrast, Casamichana and Castellano (2010) found eight-minute 5v5 soccer SSGs to elicit different demands when played on three different size playing areas, specifically, $88.9 \pm 3.9\%$ HRmax in a large area (62x44 m), $88.5 \pm 4.9\%$ HRmax in a medium area (50x35 m) and $86.0 \pm 5.8\%$ HRmax in a small area (32x23 m). Together, the above studies demonstrate that there are contrasting findings in altering playing area size in isolation in soccer SSGs.

In recognising characteristics that might influence the intensity of SSGs, the studies of Rampinini et al. (2007) and Owen et al. (2004) reported that increasing the playing area size and decreasing player number simultaneously resulted in a higher work intensity in soccer SSGs. On the other hand, a reduction in both player number and playing area size has been found to increase soccer SSG exercise intensity (Little and Williams, 2006; Little and Williams, 2007; Williams and Owen, 2007; Hill-Haas et al., 2009a; Katis and Kellis, 2009). However, it is difficult to compare the interaction effects in the above studies as the number of games, game durations and recovery durations often differ between studies (Little and Williams, 2006; Little and Williams, 2007). Moreover, the use of inconsistent playing area sizes (Aroso et al., 2004; Owen et al., 2004; Rampinini et al., 2007a; Katis and Kellis, 2009) or different playing area sizes being matched to different player number combinations in order to maintain a consistent pitch area per player (Jones and Drust, 2007; Hill-Haas et al., 2009a; Hill-Haas et al., 2010) does not allow for the effect of altering player number or playing area size to be examined in isolation (Impellizzeri et al., 2006).

Due concern also needs to be given to the reliability of SSGs so that coaches can be confident in their ability to provide a consistent aerobic training stimulus. Two studies have determined the test-retest repeatability of soccer SSGs of varying formats from 2v2 to 8v8 in an area of 30x20 to 70x45 m. The SSGs were concluded to have 'good' reliability with HR coefficients of variation [CV] values less than 3% (Little and Williams, 2006; 2007). Moreover, ratio limits of agreement (LoA) of 1.8-3.8% HRmax were also reported (Little and Williams, 2006). Similar findings by Hill-Haas et al. (2008) have also indicated that soccer SSGs provide a reliable aerobic conditioning stimulus in adolescent soccer players, with a technical error of <5% in mean HR, total distance covered and the percentage of total time moving at 0-6.9 km·h⁻¹ during soccer-specific SSGs. In contrast, Rampinini et al. (2007) reported moderate-poor reliability of physiological (%HRmax and blood lactate) and perceptual (ratings of perceived exertion; RPE) demands of four-minute soccer SSGs via LoA and CV, questioning the reliability of soccer SSGs. To date, there has been no investigation into the reliability of RL-specific SSGs, and therefore it is unclear if such games produce consistent stimuli to elicit aerobic adaptations on a test-retest basis. Finally, there has been no analysis of the effect of age on SSG variables, despite previous findings that junior RL players of different ages (<15 and <18 years) respond differently to a given training stimulus (Gabbett et al., 2008). Accordingly, the purpose of this study was to examine the effects of altering playing area size and player number on HR responses in junior RL SSGs, and the reproducibility of these responses over two repeated trials.

3.3 Methods

3.3.1 Participants and Study Design

Twenty two junior male RL players (mean age: 14.5 ± 1.5 years; stature: 172.5 ± 11.4 cm; body mass: 67.8 ± 15.1 kg; $\dot{V}O_{2\text{ peak}}$: 53.3 ± 5.6 ml·kg⁻¹·min⁻¹; HRmax: 198 ± 7.8 b·min⁻¹) volunteered to participate in the study. The players trained in two discrete age categories within a professional club; 12-13 (U13: n=8) and 15-16 (U16: n=14) years (Table 3.1). All players participated in a structured conditioning programme consisting of three resistance training and field-based conditioning sessions and one match per week. In addition, players were habituated to SSG conditioning following a three-month period of weekly SSG sessions prior to the study. These habituation sessions included an allocation of 25 minutes of SSG conditioning in the second half of each training session (subsequent to skill development). A format of four times four-minute SSGs interspersed with three minutes of activity recovery were utilised. Within this period, pilot work was conducted to determine appropriate SSG rules to elicit over 90% HRmax. SSG discipline was also trained through the use of penalties for low intensity effort such as extra runs and press ups.. Participants and their parents or guardians were fully informed of the experimental risks and provided written informed consent prior to participating in the study. The investigation was approved by the Research Ethics Committee of the Faculty of Applied and Health Sciences.

All participants performed a laboratory-based peak oxygen uptake ($\dot{V}O_{2\text{ peak}}$) test one week prior to the field testing. The field testing was conducted across two evening training sessions at the same time of day during the competitive season, on the same outside grass playing surface and under similar weather conditions. The SSGs were conducted with the player numbers and playing area sizes commonly used in high level junior RL league training, yielding six different conditions. Each SSG condition was administered on two separate occasions, seven days apart, with all 4v4 SSGs being carried out in the first session and 6v6 SSGs in the second

session. In the first session, players in the U13 age group performed two trials of the game in the small, medium and large playing areas, respectively. This order was then reversed for players in the U16 age group. In the second session the order of playing area sizes were reversed in each age group in order to minimise the occurrence of an ordering effect. The intensity of each SSG was determined as a mean percentage of HRmax, as this method has been shown to be a practical and valid measurement within soccer SSGs (Little and Williams, 2007).

Table 3.1: Participant characteristics (mean \pm SD)

Age group	Age (y)	Stature (cm)	Body mass (kg)	$\dot{V}O_{2\text{ peak}}$ (ml·kg ⁻¹ ·min ⁻¹)	HRmax b·min ⁻¹
U13 (n=8)	12.6 \pm 0.5	160.2 \pm 8.4	52.3 \pm 7.9	55.4 \pm 5.6	201.4 \pm 3.5
U16 (n=14)	15.5 \pm 0.5	179.6 \pm 5.1	76.7 \pm 10.2	52.2 \pm 5.5	196.1 \pm 8.9

3.3.2 Incremental treadmill test

Maximal oxygen uptake was determined from metabolic responses to a running protocol on a motorised treadmill (HP Cosmos, Pulsar, Hp Cosmos, Nussdorf-Traunstein, Germany). Following a three-minute warm up at 8 km·h⁻¹, participants ran for one minute at a constant speed (10 km·h⁻¹ and 11 km·h⁻¹ for the U13 and U16 players, respectively) with the treadmill set at 0% gradient. Thereafter the gradient was increased by 2% every minute until voluntary exhaustion occurred. Expired air was collected continuously using a gas analysis system calibrated following the manufacturer's guidelines (Cosmed Quark b2, Cosmed, S.r.l., Rome, Italy). Heart rate was recorded continuously during the test (Polar Team System, Polar, Oy, Finland) and averaged over five seconds intervals. On completion, the $\dot{V}O_2$ data were averaged over 15 seconds, with $\dot{V}O_{2\text{ peak}}$ defined as the highest oxygen consumption during the test and confirmed if either HR had reached within 5% of age-predicted maximum or a respiratory exchange ratio (RER) >1.15

was obtained (Rowland, 1993). Whilst not assessed in this study, such a protocol has previously been demonstrated to elicit reliable data ($r = 0.90$) among young boys (Turley, 1995).

3.3.3 Small-sided games

Heart rate responses were recorded (Polar Team System, Polar, Oy, Finland) during all 12 SSGs; 4v4 and 6v6 played in a structured sequence on 15x25 m (small), 20x30 m (medium) and 25x35 m (large) playing area sizes on two separate occasions. In the manner described by Helgerud et al. (2001) and Hoff et al. (2002), the SSGs lasted four minutes (with three minutes of active rest between each game in which players could drink ad libitum) and had standardised rules refereed by a qualified coach. The SSG was 'offside touch' and the rules were as follows: the team in possession maintained the ball until touched by a defender, a try was scored or an error was made (dropped ball, ball out of play), following which possession was turned over, running with the ball was permitted, passes in any direction were permitted, a tackle was simulated by a two handed touch from a defender, attacking players were only allowed 5 m offside from the ball carrier, play was restarted after each touch by tapping the ball with the foot to recommence play. Players were verbally encouraged to maintain a high work intensity throughout. Extra rugby balls were placed on each try line and a quick restart was encouraged to maximise the time the ball was in play.

3.3.4 Statistical Analyses

Players' mean HRs for each SSG were converted to a percentage of their HRmax obtained from the laboratory-based treadmill test. Descriptive statistics (mean \pm SD) were calculated for HR values for the sample as a whole and for each age group. The distributions of the HRmax variables were checked for normality via the Shapiro-Wilk statistic and for homogeneity of variance via the Levene statistic. These assumptions were found to be satisfied. Two three-way ANOVAs with repeated measures were conducted to assess the variability of HR responses due to the three factors (player number, playing area size, trial) in each age group, with alpha set at 0.05. Assumptions of sphericity were assessed using Mauchly's test of sphericity.

Post hoc analysis, where appropriate, were conducted via multiple Bonferroni-adjusted t-tests. The reliability of the SSGs was assessed using the LoA technique (Bland and Altman, 1986).

3.4 Results

The SSGs performed within this study elicited average HR intensities ranging from 85.0-91.5% HRmax (Table 3.4), with the 4v4 SSGs in the U16 age group eliciting above 90% HRmax for all playing area sizes (Table 3.3). The U16 age group three-way interaction (player number x playing area size x trial) was significant ($F_{2,40} = 40.4$, $P < 0.001$), though this was solely due to significant variability occurring between trials in the small 6v6 SSG ($P < 0.05$). There were no other significant interaction effects.

3.4.1 Reliability of heart rate responses

The 4v4 medium SSG was the most reliable in the U16 age group (LoA = $0.4 \pm 2.4\%$ HRmax). The 4v4 large (LoA = $0.8 \pm 2.0\%$ HRmax) and 6v6 medium (LoA = $0.8 \pm 2.9\%$ HRmax) SSGs produced the most consistent data in the U13 age group. When the two groups' data were combined, the 4v4 large and medium and the 6v6 medium were the most reliable conditions, having the narrowest LoA between SSG trial 1 and 2 (Table 3.2).

Table 3.2: Reliability statistics of SSGs (LoA)

Player number	Playing size	Overall LoA (%HRmax)	U16 (n=14) LoA (%HRmax)	U13 (n=8) LoA (%HRmax)
6v6	Small	1.9 ± 7.5	3.3* ± 6.9	0.5 ± 6.5
	Medium	0.1 ± 3.9	0.5 ± 4.2	0.8 ± 2.9
	Large	0.8 ± 5.1	0.3 ± 4.9	1.8 ± 4.9
4v4	Small	0.1 ± 4.1	0.4 ± 3.4	0.6 ± 5.1
	Medium	0.2 ± 4.4	0.4 ± 2.4	0.1 ± 6.9
	Large	0.9 ± 3.1	0.9 ± 3.6	0.8 ± 2.0

*Significant difference between trials ($P<0.05$)

3.4.2 Player number

Analysis of variance indicated that there was a significant main effect of player number in the U16 age group ($F_{1,13}=40.4$, $P<0.001$), with mean HR being higher in the 4v4 (90.6% HRmax) than the 6v6 SSGs (86.2% HRmax), independent of playing area size (Table 3.3). There were no significant difference in HR intensity between the 4v4 (88.1% HRmax) and 6v6 (89.3% HRmax) conditions in the U13 age group ($F_{1,7}=2.987$, $P=0.128$; Table 3.3).

3.4.3 Playing area size

There was no significant effect of playing area size with mean HRs of 87.4%, 88.8% and 89.0% HRmax in the small, medium and large playing areas, respectively, in the U16 age group. There was also no significant effect in the U13 age group ($F_{2,14}= 1.0$, $P=0.13$) with %HRmax values of 88.2%, 88.7% and 89.3% for small, medium and large playing areas, respectively (Table 3.3).

Table 3.3: HR intensity (%HRmax) for each variable (mean \pm SD)

Age Group	Player Number		Playing Area Size			Trial	
	4v4	6v6	Small	Medium	Large	1	2
U13 (n=8)	88.1 \pm 4.2	89.3 \pm 4.0	88.2 \pm 3.9	88.7 \pm 4.3	89.3 \pm 4.0	89.0 \pm 4.1	88.5 \pm 4.1
U16 (n=14)	90.6 \pm 2.4	86.2 \pm 3.5*	87.4 \pm 4.2	88.8 \pm 3.3	89.0 \pm 3.5	88.2 \pm 4.2	88.6 \pm 3.2

*Significant difference in player number in the U16 age group (4v4 and 6v6, $P < 0.05$)

Table 3.4: HR intensity (%HRmax) for each SSG condition with trials combined (mean \pm SD)

	U16 (n=14)			U13 (n=8)		
	Small	Medium	Large	Small	Medium	Large
4v4	89.8 \pm 2.2	90.6 \pm 2.80	91.5 \pm 1.9	87.9 \pm 4.1	88.1 \pm 4.5	88.4 \pm 4.6
6v6	85.0 \pm 4.1	87.0 \pm 2.8	86.5 \pm 2.9	88.5 \pm 4.1	89.3 \pm 4.4	90.3 \pm 3.5

3.5 Discussion

From a coach's perspective, it is imperative that SSGs can stimulate physiological responses that are reproducible in order that they can use SSGs as part of a periodised training programme. Importantly, such consistency needs to be achieved by most, if not all, players and the extent of this is best reflected in the random error component of the 95% LoA statistic. In considering the data overall, and in the absence of any comparable figures for RL, the LoA enable a favourable interpretation of the reliability of the HR responses (within 1.9% HRmax) in all the SSGs apart from the small 6v6 condition (see above). This judgement is qualified on the basis that, in the worse case scenario (6v6 large), HRs (for 95% of the players) were no more than approximately 5% HRmax higher or lower in trial 2 compared to trial 1, reflecting that, in most cases, intensities of greater than 85% HRmax were achieved in both trials. This pattern was found to be independent of age group, albeit with the exception referred to above and the 4v4 medium SSG played by the U13 year-olds, for which the variability was up to about 7% HRmax between trials. Particular SSGs could be singled out in each group as being the most reliable, for example, the 4v4 large (U13) and 4v4 medium (U16), with random error between trials being less than 3% HRmax, but it would be difficult to provide a viable explanation for this.

The SSGs performed within this study elicited mean HR intensities above 85% HRmax, which are considered to be both 'high' in competitive junior RL (Estell et al. 1996) and above match intensity (Coutts et al., 2003). The 4v4 SSGs elicited an average HR intensity above 90% HRmax within the older players (U16 years), demonstrating that SSGs specific to RL can elicit the recommended SSG HR intensity for aerobic conditioning (Hoff et al., 2002). Moreover, variables which achieved 85% HRmax (6v6 SSGs with the U15s and 4v4 and 6v6 in U13s) would have achieved an intensity from which anaerobic development and some aerobic development can occur. The mean HR responses during the 4v4 SSGs were consistently higher than those of the 6v6 SSGs, albeit among the older junior players only. Whilst it is not possible to quantify this, a likely explanation for the difference in HR

response between 4v4 and 6v6 SSGs was the occurrence of a greater frequency of contact with the ball and overall individual involvement when player number was reduced (Platt et al., 2001; Owen et al., 2004; Jones and Drust, 2007; Katis and Kellis, 2009). Though it is unsatisfactory to compare directly the physiological responses of sport-specific SSGs, this effect is consistent with previous research among soccer players (Little and Williams, 2007; Rampinini et al., 2007). Moreover, that we observed no difference in mean HR between the 4v4 and 6v6 SSGs in our U13 age group is of more immediate interest, and may reflect a developmental issue with respect to spatial awareness.

As adults exhibit a much better distinction of extra-personal space when compared to children (Gabbard et al., 2007), in an applied context this might translate into younger players demonstrating a poorer spatial awareness compared to older players during SSGs wherein a defined area of play is employed. This would cause them, regardless of the player number and therefore the amount of space available, to self-restrict the area in which they work. Additionally, such individuals might be more inclined to focus their attention on the point of interest, that is, the ball or the player holding the ball, rather than events occurring elsewhere. Accordingly, the findings of this Chapter tentatively support the anecdotal evidence posited by coaches that young players tend to play in a confined area even when considerable space is available to them. On this theme, one could speculate that increasing playing area size would result in an increase in intensity due to players having more space in which to play and having more scope to be exertive. However, in both the U16 and U13 age groups, there was no significant difference in the observed HRs between the three playing area sizes. Taken at face value, this finding suggests that the area sizes typically used by RL coaches do not independently contribute to the challenge of optimising SSG intensity for aerobic conditioning among junior players.

The interaction between player number and area size revealed no effect on mean HR, though when the variance over the two trials was also considered the resulting three-way interaction was significant in the U16 age group.

Whilst post hoc analysis identified this was owing to a significant mean difference (decrease) occurring between trials in the small 6v6 SSG only, other than suggesting that the relatively restricted space in this condition might have been a factor, it is difficult to explain. This is particularly so as the mean HR responses in all the other SSGs were found to be consistent (within $\pm 1.9\%$ HRmax) over the repeated trials. Nonetheless, the issue of the reliability of the SSGs deserves further scrutiny.

3.6 Conclusions and practical applications

Small-sided games are being used frequently as a conditioning stimulus within RL at National and Super League levels. The purpose of the current research is to develop a format for employing SSGs in a way that will enable coaches to optimise such conditioning. The present study is the first to report the HR responses and repeatability of these responses to altering playing area size and player number in RL specific SSGs within two junior age groups. Whilst the majority of SSG studies do not state SSG specifications, the offside nature of the SSGs utilised within this study is a potential limitation. However, a conditioning SSG which incorporates key game-related skills (evasion, support play, peripheral vision, spatial awareness, game awareness) and is widely utilised within RL training was selected through consultation with senior coaches within the professional game.

The findings demonstrate that SSGs can elicit high and repeatable HR responses adequate for aerobic conditioning. Altering playing area size had no effect, whereas player number was found to elicit different HR responses for junior players of different ages, suggesting that coaches should be cognisant of the potential mediating effect that age and player number might impose upon SSGs. Specifically, that older junior players experienced a higher training stimulus from 4v4 SSGs than 6v6 SSGs, and younger junior players experienced the same training stimulus in both 4v4 and 6v6 SSGs. Therefore, conditioning coaches should be aware that 4v4 SSGs elicit a stronger aerobic conditioning stimulus than 6v6 SSGs in older junior players,

and that altering the player number will not affect the SSG intensity in younger junior players. Moreover, coaches can be confident that utilising SSGs will provide a consistent training stimulus within conditioning programmes.

Chapter 4:

Game actions and heart rates observed during small-sided games, with and without coach encouragement

The contents of this chapter form the basis of the following presentations:

Presentations:

Foster, C. Twist, C. Lamb, K. Nicholas, C. (2008). Heart rate responses to attacking and defending in coached and uncoached rugby league small-sided games. *British Association of Sport and Exercise Sciences Conference*, Brunel University, UK.

Foster, C. (2009). Factors to consider in the application of small-sided games for aerobic conditioning. *RFL Sport Science, Medicine and Performance Conference*. Leeds, UK.

Foster, C. Twist, C. Lamb, K. Nicholas, C. (2009). The technical demands of attacking and defending in coached and uncoached rugby league small-sided games. *14th Annual Congress of the European College of Sport Science*, Oslo, Norway.

4.1 Abstract

This study investigated the HR responses and incidence of specific game actions during attacking and defending play in SSGs, with and without coach encouragement. Additionally, the repeatability of the HR responses to these SSGs was assessed on a test-retest basis. Seventeen boys from a professional club (mean age: 13.4 ± 1.1 yr; stature: 168 ± 11.8 cm; body mass: 61.5 ± 14.9 kg; $\dot{V}O_{2\text{ peak}}$: 55.0 ± 5.6 ml·kg⁻¹·min⁻¹; HRmax: 202 ± 6.5 b·min⁻¹) participated in two repeated trials of four, four-minute conditioned SSGs over a two-week period. Within each trial, the players engaged in separate attacking and defending roles, with and without coach encouragement. HRs were recorded continuously in each game and expressed as age-related (U13 and U15) %HRmax, HRpeak and time spent within the following HR Zones: Zone 1 ($\geq 90\%$ HRmax), Zone 2 (85-89.9% HRmax), Zone 3 (75-84.9% HRmax) and Zone 4 ($\leq 74.9\%$ HRmax). Each SSG was video recorded for subsequent analysis of the prevalence of specific game actions. It was observed that attacking play elicited a greater average SSG intensity than defending play ($90.7 \pm 3.3\%$ versus $87.6 \pm 2.2\%$ HRmax) and a greater amount of time in HR Zone 1 (62.0 ± 31.5 versus $48.4 \pm 31.3\%$ of total time). Compared to the older junior players (U15), the younger junior players (U13) elicited a greater average SSG intensity ($90.5 \pm 1.7\%$ versus $87.9 \pm 0.6\%$ HRmax), spent a greater amount of time in HR Zone 1 ($68.6 \pm 22.5\%$ versus $43.3 \pm 34.6\%$ of total time) and less time in HR Zones 2, 3, and 4 (Zone 2, $15.7 \pm 15.4\%$ versus $26.1 \pm 24.1\%$ of total time; Zone 3, $10.2 \pm 9.8\%$ versus $22.6 \pm 24.4\%$ of total time; and Zone 4, $5.6 \pm 3.8\%$ versus $8.0 \pm 4.6\%$ of total time). Moreover, compared to the U15 players, the U13 players completed a greater volume of successful passes (21.3 ± 0.0 versus 17.4 ± 3.1), pass plays (6.6 ± 1.4 versus 3.0 ± 0.5) and tries (2.5 ± 1.1 versus 0.6 ± 0.3), but a lower volume of dummy runs (10.6 ± 1.8 versus 18.9 ± 1.8), successful touches (30.5 ± 0.5 versus 42.1 ± 1.1) and completed sets (1.6 ± 0.0 versus 3.5 ± 0.6). In addition, the game actions demonstrated large trial-trial variability. The addition of coach encouragement had no effect on the HR responses or volume of game actions conducted.

The SSGs demonstrated large trial-trial variability in average and peak HR intensities (bias of $3.7 \pm$ and $\pm 4\%$ HRmax) and percentage of time in HR Zones (bias of $\pm 25\%$ percentage of time). Moreover, the associated random errors observed were notable (up to ± 13.5 and 26.7% HRmax for average and peak HR intensities, and up to $\pm 95\%$ for the time spent in the lowest HR zone), and indicative of poor reliability. The implications of the current findings are that those who regularly use SSGs (conditioning coaches) need to be aware of the potential mediating effect that player role and age have on the intensity and game actions generated in a given SSG, and the importance of habituation to SSG format and intensity in achieving intensities appropriate for aerobic development. Moreover, coaches need to be aware that manipulating SSG rules can adversely affect the reproducibility of HR responses.

4.2 Introduction

It is imperative from a conditioning perspective to determine if there are any differences in the physiological demands of attacking and defending in SSGs in order to be able to manipulate and control exercise intensity and therefore the conditioning stimulus. Moreover, the analysis of player role (attack versus defence) within SSGs would determine if SSGs represent the physiological demands of those roles observed in competitive play. Although various SSG variables such as playing area size, player number and coach encouragement have been investigated within team sports SSGs (Owen et al., 2004; Tessitore et al., 2006; Jones and Drust, 2007; Rampinini et al., 2007; Kelly and Drust, 2009; Foster et al., 2010), there has been no analysis into the physiological demands of attacking and defending, despite SSGs commonly being utilised as a conditioning method for RL players (Gabbett, 2005e). A recent study by Sykes et al. (2009) has shown defending work-to-rest ratios (WRR) to be significantly higher than attacking WRR in elite senior RL players during competitive matches. Such disparities were attributed to players spending less time in low intensity activity when defending due to the requirement of the defensive line to retreat 10 m following the completion of a

tackle before recommencing play, whereas those players in attack are only required to retreat to the back foot of the tackled player.

Previous studies have reported greater increases in strength following supervised resistance training by a coach compared to unsupervised sessions in trained (Mazzetti et al., 2000; Coutts et al., 2004; Ratamess et al., 2008) and untrained participants (Gentil and Bottaro, 2010). The greater strength gains from supervised sessions were predominantly attributed to increases in training intensity (Mazzetti et al., 2000; Coutts, 2004), training attendance (Coutts, 2004), training volume (Mazzetti et al., 2000) and the more frequent use of maximum repetitions (Gentil and Bottaro, 2010). Additionally, the strength gains reported by Coutts et al. (2004) were attributed to neural adaptation and an improved learning of the lifting technique, implying that supervised programmes reinforcing correct lifting technique would result in greater strength gains than unsupervised programmes. Furthermore, Mazzetti et al. (2000) suggested that psychological factors could contribute to increased performance within supervised resistance training programmes due to athletes experiencing greater competitiveness and increased external motivation in the form of verbal encouragement. In agreement with the notion that coached SSGs increase player motivation (Impellizzeri et al., 2006), Rampinini et al. (2007) reported that soccer SSGs which involved coach encouragement elicited significantly higher exercise intensities (88.7% HRmax) than SSGs in which the coach played a passive role (86.5% HRmax). Moreover, coach encouragement was reported to have a greater influence on the physiological responses to SSGs than altering the player number or playing area size. Consequently, it would be interesting to determine if there are any differences in physiological performances within RL SSGs conducted with and without coach encouragement.

There has been no analysis of the effect of age on SSG variables, despite previous findings that junior RL players of different ages (<15 and <18 years) respond differently to a given training stimulus (Gabbett et al., 2008). Moreover, findings from Chapter 3 of this thesis reported different HR

responses to altering player number in RL SSGs among older and younger junior players (U16 and U13, respectively), with older players eliciting a greater HR response during 4v4 games compared to 6v6 ($90.6 \pm 2.4\%$ versus $86.2 \pm 3.5\%$ HRmax), whereas younger players reported no difference in exercise intensity between games ($88.1 \pm 4.2\%$ versus $89.3 \pm 4.6\%$ HRmax). Regardless of the space available during games, it is possible that younger players might possess poorer spatial awareness (Gabbard et al., 2007) and therefore self-restrict the area in which they work. From the perspective of designing and implementing SSGs with young players of different ages, further investigation into the HR responses obtained in younger and older junior RL players during SSGs is warranted.

So that coaches can be confident in the ability of SSGs to provide a consistent aerobic training stimulus, due concern also needs to be given to the reliability of such training methods. Two studies have determined the test-retest repeatability of soccer SSGs of varying formats from 2v2 to 8v8 in an area of 30x20 to 70x45 m. The SSGs were concluded to have good reliability with HR coefficients of variation (CV) values less than 3% (Little and Williams, 2006; 2007). Moreover, ratio limits of agreement (LoA) of 1.8-3.8% HRmax were also reported (Little and Williams, 2006). Similar findings by Hill-Haas et al. (2008) have also indicated that soccer SSGs provide a reliable aerobic conditioning stimulus in adolescent soccer players, with a technical error of <5% in mean HR, total distance covered and the percentage of total time moving at $0-6.9 \text{ km}\cdot\text{h}^{-1}$. Indeed, LoA statistics conducted on the RL SSGs utilised in Chapter 3 of this thesis revealed SSG intensity to be no more than approximately 5% HRmax higher or lower in Trial 2 compared to Trial 1, which was suggested to be an acceptable level of reliability. In contrast, Rampinini et al. (2007) reported moderate-poor reliability of physiological (%HRmax and blood lactate) and perceptual (ratings of perceived exertion; RPE) demands of four-minute soccer SSGs via LoA and CV, so further investigation is required. Additionally, although studies have examined the reliability of altering SSG variables such as playing number and playing area size (Little and Williams, 2006), there has

been no further analysis of how the presence of coach encouragement affects the reliability of SSG intensity, despite previous findings that the addition of coach encouragement increases SSG intensity (Rampinini et al., 2007). Furthermore, a detailed reliability analysis of opposing player roles would allow the consistency of the aerobic training stimulus of attacking and defending within SSGs to be determined.

A well devised SSG training session enables concurrent training of technical skill and fitness through attention to game rules, format and delivery (Impellizzeri et al., 2006). Moreover, a game-specific training approach promotes an active technical transfer to match environment as technical skills are carried out under similar training conditions (Williams et al., 2003). Whilst the majority of studies have analysed the frequency of technical actions (such as number of passes, tackles, dribbles, headers) within soccer SSGs (Platt et al., 2001; Owen et al., 2004; Tessitore et al., 2006; Jones and Drust, 2007; Mallo and Navarro et al., 2007; Katis and Kellis, 2009; Kelly and Drust, 2009; Fanchini et al., 2011), there has been limited investigation into the technical demands imposed during RL SSGs (Gabbett et al., 2010) or the success rate of technical actions performed (Platt et al., 2001; Gabbett et al., 2010). To date there has been no analysis on the effect of coach encouragement on the volume and success rate of game actions within SSG studies. Such a study would provide a useful insight into the technical demands of SSGs, how they reflect match play actions, their consistency between games and whether these demands are affected by coach involvement.

Small-sided games have been reported to be a reliable (Little and Williams, 2006; Hill-Haas et al., 2008) and appropriate (Helgerud et al., 1991, Hoff et al., 2002) conditioning method for team sports players. However, whilst authors have examined the effect of altering SSG variables on HR intensity there has been limited investigation into the HR and technical demands of player role and the effects of coach encouragement on these demands. Accordingly, the purpose of this study was to examine the HR responses and

game actions of attacking and defending in SSGs with and without coach encouragement in two different junior age groups and to determine the reproducibility of these responses over two repeated trials.

4.3 Methods

4.3.1 Participants and study design

Seventeen junior male RL players (mean age: 13.4 ± 1.1 years; stature: 1.68 ± 11.8 m; body mass: 61.5 ± 14.9 kg, $\dot{V}O_{2\text{ peak}}$ 55.0 ± 6.4 ml·kg⁻¹·min⁻¹, HRmax: 202 ± 6.5 b·min⁻¹) volunteered to participate in eight four-minute conditioned SSGs. The players trained in two discrete age categories within a professional club; 12-13 (U13: $n=8$) and 14-15 (U15: $n=9$) years (see Table 4.1). All players participated in a structured conditioning programme consisting of three resistance training and field-based conditioning sessions and one match per week. In addition, players were habituated to SSG conditioning following a three-month period of weekly SSG sessions prior to the study. These habituation sessions included an allocation of 25 minutes of SSG conditioning in the second half of each training session (subsequent to skill development). A format of four times four-minute SSGs interspersed with three minutes of activity recovery were utilised. Within this period, pilot work was conducted to determine appropriate SSG rules to elicit over 90% HRmax. SSG discipline was also trained through the use of penalties for low intensity effort such as extra runs and press ups. Participants and their parents or guardians were fully informed of the experimental risks and provided written informed consent prior to participating in the study. The investigation was approved by the Research Ethics Committee of the Faculty of Applied and Health Sciences.

All participants performed a laboratory-based assessment of peak oxygen uptake ($\dot{V}O_{2\text{ peak}}$) one week prior to the field testing. The SSG trials were administered on two separate occasions, seven days apart at the same time of day during the competitive season, on the same outside grass playing surface and under similar weather conditions. The SSGs were conducted

with a player number (4v4) and playing area size (20x30 m) commonly used in RL training, which has been found to elicit high and repeatable HR responses adequate for aerobic conditioning in high-level junior RL players (Chapter 3).

Table 4.1: Participant characteristics (mean \pm SD)

Group	Age (y)	Stature (cm)	Body mass (kg)	$\dot{V}O_{2\text{ peak}}$ (ml·kg ⁻¹ ·min ⁻¹)	HRmax (b·min ⁻¹)
U13 (n=8)	12.4 \pm 0.5	159.4 \pm 10.4	53.2 \pm 13.1	54.8 \pm 6.2	204 \pm 7
U15 (n=9)	14.3 \pm 0.5	176.9 \pm 4.5	68.9 \pm 12.8	55.2 \pm 6.9	201 \pm 6.2

4.3.2 Incremental treadmill test

Maximal oxygen uptake was determined from metabolic responses to a running protocol on a motorised treadmill (HP Cosmos, Pulsar, Hp Cosmos, Nussdorf-Traunstein, Germany). Following a three-minute warm up at 8 km·h⁻¹, participants ran for one minute at a constant speed (10 km·h⁻¹ and 11 km·h⁻¹ for the U13 and U15 players, respectively) with the treadmill set at 0% gradient. Thereafter the gradient was increased by 2% every minute until volitional exhaustion occurred. Expired air was collected continuously using a gas analysis system calibrated following the manufacturer's guidelines (Cosmed Quark b2, Cosmed, S.r.l., Rome, Italy). Heart rate was recorded continuously during the test (Polar Team System, Polar, Oy, Finland) and averaged over five second intervals. On completion, the $\dot{V}O_2$ data were averaged over 15 seconds, with $\dot{V}O_{2\text{ peak}}$ defined as the highest oxygen consumption during the test and confirmed if either HR had reached within 5% of age-predicted maximum or a respiratory exchange ratio (RER) >1.15 was obtained (Rowland, 1993). Whilst not assessed in this study, such a protocol has previously been demonstrated to elicit reliable data ($r = 0.90$) among young boys (Turley, 1995).

4.3.3 Small-sided games

Players engaged in SSGs with and without coach encouragement in both attacking and defensive roles (non-contact). The order of the SSGs with and without coach encouragement was counter balanced across the two trials in order to eliminate any effects of fatigue. The SSGs with coach encouragement consisted of three United Kingdom Coaching Certificate (UKCC) Level Two RL coaches spread out around the outside of the pitch verbally encouraging players to increase their work intensity. The instructions were standardised inasmuch that the coaches were encouraged to use positive motivating words such as drive, push up, reset and sprint. The coaches maintained their positions around the pitch and remained silent for the SSGs without coach encouragement. In the manner described by Helgerud et al. (2001) and Hoff et al. (2002), the SSGs lasted for four minutes (with three minutes of active rest between each game in which players could drink ad libitum) and had standardised rules refereed by a qualified coach. The SSG had standardised rules and all games were refereed by the same coach (qualified as above). The SSG was developed following coach input of existing conditioning games and the rules were as follows: players either attacked or defended for the entire game with no turnover of possession permitted; players were only allowed to pass the ball backwards; running in any direction with the ball was permitted; a four repeat touch limit was employed (four plays within each set of play); all players had to return to their starting position after either scoring a try, end of a set or error (knock on, forward pass); the same team always restarted play following resetting to their starting positions; a tackle was simulated by a two handed touch from a defending player; following each touch, play was restarted by an attacking player passing the ball uncontested between their feet to another attacking player ('play-the-ball', PTB) whilst the remaining attacking players carried out a press up and defending players retreated five metres. Extra rugby balls were placed on each try line and a quick restart was encouraged to maximise the time the ball was in play.

4.3.4 Heart rate analysis

The HR responses to each SSG condition were recorded (Polar Team System, Polar, Oy, Finland) and expressed overall and for each age group (U13 and U15). Heart rate analysis included peak and average HR (as a percentage of maximum; %HRmax) and time spent in the HR zones previously used in junior soccer SSGs (Hill-Haas et al., 2009a; Hill-Haas et al., 2009b; Hill-Haas et al., 2009c; Casamichana and Castellano, 2010; Hill-Haas et al., 2010): Zone 1 ($\geq 90\%$ HRmax), Zone 2 (85-89.9% HRmax), Zone 3 (75-84.9% HRmax) and Zone 4 ($\leq 74.9\%$ HRmax). Previous studies that have used a similar SSG format have reported average game intensities in Zone 1 above 90% HRmax (Hoff et al., 2002; Chamari et al., 2005; Impellizzeri et al., 2006; Kelly and Drust, 2009), which have been regarded as an appropriate intensity for aerobic conditioning within four-minute high-intensity intervals (Helgerud et al., 2001; Helgerud et al., 2007).

4.3.5 Technical analysis

The SSGs were filmed using a Cannon MV890 minDV video recorder from the pitch side (zoomed in and following play around the activity of the ball). A retrospective analysis was carried out by a Level 2 coach using SportsCode (Version 8.5.2). Ten game actions were developed (Figure 4.1) from the Rugby Football League Official Laws (game actions 1-3, Rugby Football League, 2012) the Rugby Football League (RFL) coaching guidelines (game actions 4-7, Webb, 2006) and previous definition (game actions 8-10, Eaves and Broad, 2007). These game actions were assigned a keyboard symbol and operational definition (Figure 4.1). An assessment of intra-operator reliability was conducted on two identical SSGs, seven days apart, which indicated that the level of agreement was acceptable (percentage difference values less than 5%). This agreement concurs with previous studies that have assessed intra-operator agreement of game actions within competitive rugby union (Hughes et al., 2002; Eaves et al., 2003) and RL (Eaves and Broad, 2007).

Number	Game Action	Symbol	Operational Definition
1	Try	T	A grounded ball by a player in their opponents in-goal area
2	Error	E	Loss of possession due to ball being thrown out of playing area or to the opposing team, knock on (knocking the ball towards the opponent's dead ball line with hand or arm), forward pass (a throw towards the opponent's dead ball line)
3	Completed Set	Q	Handover of possession following a completed set of four successive PTBs
4	Successful touch	5	A defending player touching an attacking player in possession of the ball with both hands (two handed touch defence)
5	Unsuccessful touch	6	A defending player touching an attacking player in possession of the ball with only one hand or missing a touch
6	Successful pass	2	A throw from the 6 o'clock position (wrists flicked over and ball pointing to the floor) which is received by the attacking player at a height between their hips and shoulders
7	Unsuccessful pass	3	A throw which is either not made from the 6 o'clock position (wrists flicked over and ball pointing to the floor) or is not received by the attacking player at a height between their hips and shoulders.
8	Dummy run	D	A run with the ball by the acting half-back direct from the PTB
9	Hit up	H	A single pass from the acting half-back to a player who carried the ball direct into contact
10	Pass play	P	A ball which is passed at least twice between the PTB and subsequent carry into contact

Figure 4.1 Game action symbols and operational definitions

4.3.6 Statistical Analysis

Players' mean HRs for each SSG were converted to a percentage of their HRmax obtained from the laboratory-based treadmill test. Descriptive statistics (mean \pm SD) were calculated for %HRmax, HRpeak and time spent in HR zones for each age group. The distributions of the HR values were checked for normality via the Shapiro-Wilk statistic and homogeneity of variance via the Levene statistic. These assumptions were found to be satisfied for the majority of conditions. A four-way ANOVA with repeated measures was conducted on each HR variable (%HRmax, HRpeak and each HR zone) to assess the variability of HR responses across the within subjects factors (coach role, player role, trial) and the between subjects factor of age. Post-hoc analyses, where appropriate, were conducted via multiple Bonferroni-adjusted t-tests. An analysis of test-retest reliability was conducted using the LoA technique (Bland and Altman, 1986), despite the majority of distributions of the HR variables producing heteroscedastic errors, to enable a comparison to the reliability statistics of previous SSG studies.

The game action frequencies were averaged over the two trials to examine any affects of coach encouragement or player age on game actions. In addition, the percentage difference of game actions from trial 2 to trial 1 was investigated to examine the repeatability between trials. Game action results are presented as descriptive statistics as there were too few SSGs (x4) in each condition (with and without coach encouragement) to justify hypothesis tests between the two age groups or trials. Due to practical issues regarding player access and availability it was not possible to carry out any further SSGs. In order to report the game actions appropriately and to allow comparison to other studies, the mean and median are reported with 95% confidence limits, as suggested by Eaves et al. (2005)

4.0 Results

4.4.1 Reliability of heart rate responses

LoA generally revealed poor reproducibility of the HR responses to the SSGs imposed (see Tables 4.2-4.7). The LoA for SSG peak and average HR values revealed differences as high or low as 13.6% and 26.7% HRmax in the worse case scenario. LoA revealed differences as high or low as 95.8, 69.8, 65.8 and 17.3% HRmax for the percentage of time spent in HR zone 1, 2, 3 and 4, respectively.

Table 4.2: Reliability of HRmax responses across two trials

Coach Role	Player Role	Overall	U13	U15
		LoA (%HRmax)	LoA (%HRmax)	LoA (%HRmax)
With	Defend	2.6 ± 11.4	1.5 ± 8.7	3.7 ± 13.6
	Attack	1.9 ± 8.0	2.3 ± 10.7	1.7 ± 5.3
Without	Defend	-0.4 ± 11.8	0.1 ± 11.8	-0.9 ± 12.5
	Attack	-0.7 ± 8.3	-1.6 ± 5.7	-1.6 ± 10.1

Table 4.3: Reliability of HRpeak responses

Coach Role	Player Role	Overall	U13	U15
		LoA (%HRmax)	LoA (%HRmax)	LoA (%HRmax)
With	Defend	2.8 ± 10.1	1.4 ± 8.1	4.0 ± 11.6
	Attack	-0.4 ± 12.3	1.0 ± 11.7	-1.6 ± 13.0
Without	Defend	0.2 ± 4.9	-0.4 ± 6.2	0.7 ± 3.6
	Attack	-2.0 ± 18.6	-2.0 ± 26.7	-2.0 ± 8.3

Table 4.4: Reliability of percentage of time spent in HR zone 1

Coach Role	Player Role	Overall	U13	U15
		LoA (% time)	LoA (% time)	LoA (% time)
With	Defend	19.0 ± 82.8	13.6 ± 74.3	23.8 ± 93.1
	Attack	-9.5 ± 90.8	-25.0 ± 79.7	4.3 ± 95.8
Without	Defend	4.2 ± 45.4	3.7 ± 42.5	4.6 ± 50.4
	Attack	-7.1 ± 64.5	0.8 ± 22.8	-14.1 ± 86.2

Table 4.5: Reliability of percentage of time spent in HR zone 2

Coach Role	Player Role	Overall	U13	U15
		LoA (% time)	LoA (% time)	LoA (% time)
With	Defend	-5.1 ± 58.3	-11.9 ± 42.6	0.9 ± 69.8
	Attack	9.4 ± 65.8	25.0 ± 52.0	-4.5 ± 67.3
Without	Defend	-2.6 ± 32.9	-4.2 ± 18.1	-1.2 ± 43.2
	Attack	-5.1 ± 37.8	-2.9 ± 14.8	-7.2 ± 51.2

Table 4.6: Reliability of percentage of time spent in HR zone 3

Coach Role	Player Role	Overall	U13	U15
		LoA (% time)	LoA (% time)	LoA (% time)
With	Defend	-15.1 ± 59.3	-6.8 ± 32.9	-22.4 ± 74.7
	Attack	-0.7 ± 45.8	-1.8 ± 34.7	0.2 ± 56.0
Without	Defend	-0.1 ± 19.2	0.6 ± 16.9	-0.7 ± 22.0
	Attack	13.0 ± 51.8	1.3 ± 6.8	23.4 ± 65.8

Table 4.7: Reliability of percentage of time spent in HR zone 4

Coach Role	Player Role	Overall	U13	U15
		LoA (% time)	LoA (% time)	LoA (% time)
With	Defend	1.2 ± 15.7	5.1 ± 9.6	-2.3 ± 17.3
	Attack	0.8 ± 10.11	1.8 ± 7.7	-0.0 ± 12.1
Without	Defend	-1.2 ± 13.0	0.5 ± 15.1	-2.8 ± 10.8
	Attack	-0.6 ± 9.1	1.0 ± 8.4	-2.1 ± 9.1

4.4.2 Percentage of maximal heart rate and peak heart rate

The mean and HRpeak intensities elicited within the present SSGs ranged from 86.7 ± 2.2 to $92.4 \pm 1.7\%$ HRmax and 92.2 ± 4.2 to $96.4 \pm 3.8\%$ HRmax, respectively (Table 4.8). The average time spent in each HR zone ranged from 5.0 ± 3.2 to $78.9 \pm 9.9\%$ of total time (Table 4.9).

Table 4.8: HR intensity and HRpeak (trials combined and presented as mean \pm SD %HRmax)

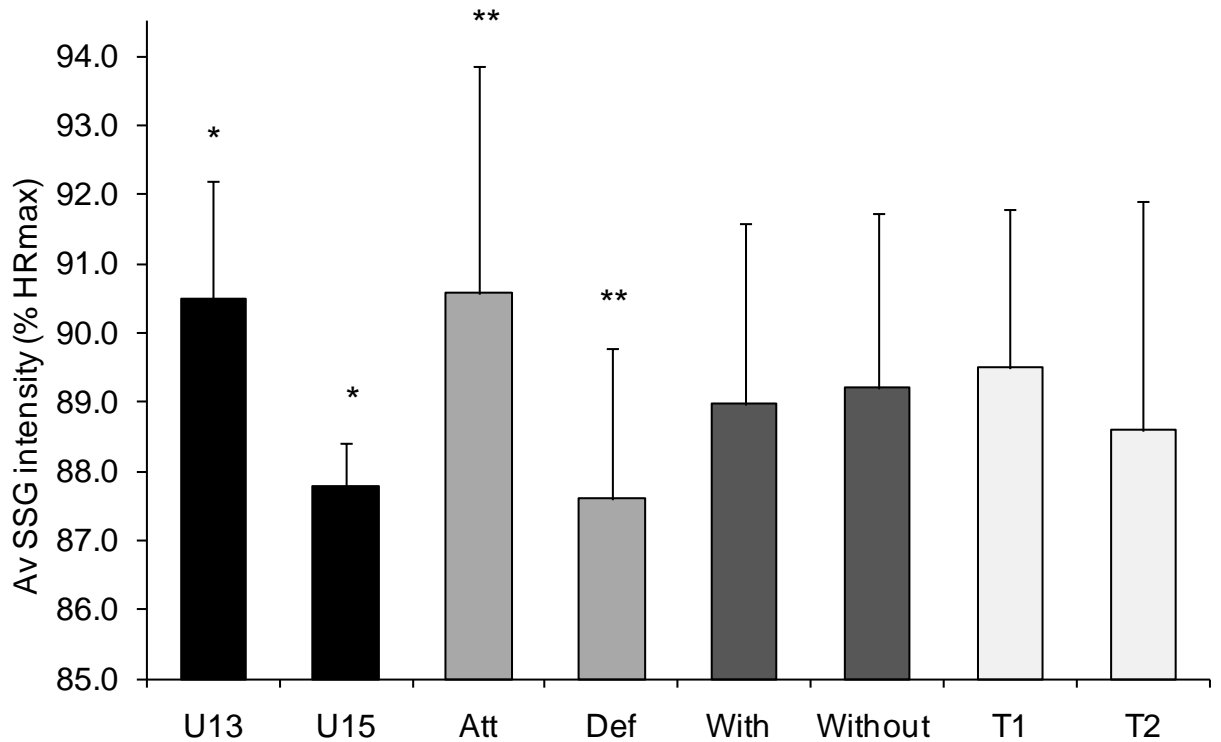
		Defending	Attacking	With CE	Without CE
U13	Mean HR	88.6 \pm 1.8	92.4 \pm 1.7	90.5 \pm 1.3	90.5 \pm 2.1
	HRpeak	94.7 \pm 4.8	96.1 \pm 6.9	96.4 \pm 3.8	94.3 \pm 7.3
U15	Mean HR	86.7 \pm 2.2	89.0 \pm 3.6	87.6 \pm 2.8	88.1 \pm 2.4
	HRpeak	92.2 \pm 4.4	92.9 \pm 4.4	92.2 \pm 4.2	92.7 \pm 4.6

CE = coach encouragement

Table 4.9: Time spent in each HR zone (trials combined and presented as mean \pm SD % of total time)

		Defending	Attacking	With CE	Without CE
U13	Zone 1	58.1 \pm 26.5	78.9 \pm 9.9	68.2 \pm 20.4	66.6 \pm 24.6
	Zone 2	22.4 \pm 18.8	9.0 \pm 6.1	14.0 \pm 12.3	18.3 \pm 17.9
	Zone 3	13.2 \pm 12.6	7.3 \pm 4.1	11.1 \pm 10.2	10.2 \pm 9.6
	Zone 4	6.3 \pm 3.5	5.0 \pm 4.0	6.8 \pm 4.2	5.0 \pm 3.2
U15	Zone 1	41.3 \pm 33.1	46.8 \pm 36.2	42.3 \pm 34.1	44.3 \pm 35.5
	Zone 2	29.0 \pm 24.9	39.9 \pm 76.0	27.2 \pm 25.1	41.8 \pm 75.6
	Zone 3	21.8 \pm 23.5	21.9 \pm 25.7	22.0 \pm 25.3	23.1 \pm 23.9
	Zone 4	7.9 \pm 4.9	8.1 \pm 4.3	8.6 \pm 5.1	7.5 \pm 4.0

CE = coach encouragement



* Significant difference between age groups ($P < 0.05$).

** Significant difference between player role ($P < 0.05$). Att = attacking, Def = defending, With = with coach encouragement, Without = without coach encouragement, T1 = trial 1, T2 = trial 2

Figure 4.2: Mean \pm SD of SSG intensity for each factor (age, player role, coaches role and trial).

Analysis of variance revealed a significant main effect of player role ($F_{(1,15)} = 23.5$, $P < 0.05$), with attacking play eliciting a greater HR intensity than defending play ($90.7 \pm 3.3\%$ and $87.6 \pm 2.2\%$ HRmax, respectively, Figure 4.2). Moreover, the effect of age was also significant ($F_{(1, 15)} = 6.7$, $P < 0.05$; Figure 4.2), with the younger junior players eliciting a higher average SSG intensity than the older junior players ($90.5 \pm 1.7\%$ versus $87.9 \pm 0.6\%$ HRmax). Neither the effect of coach role ($F_{(1, 15)} = 0.2$, $P > 0.05$) nor trial ($F_{(1, 15)} = 1.5$, $P > 0.05$) was significant. In addition, there was a significant coach role by trial effect ($F_{(1, 15)} = 18.2$, $P < 0.05$), which post hoc analysis revealed was due to the intensity in trial 1 being higher than trial 2 in SSGs with coach encouragement ($t_{(16)} = 3.01$, $P < 0.025$).

There were no significant main effects of player role ($F_{(1, 15)} = 1.0, P>0.05$), coach role ($F_{(1, 15)} = 1.3, P>0.05$), age ($F_{(1, 15)} = 3.6, P>0.05$), or trial ($F_{(1, 15)} = 0.0, P>0.05$) on HRpeak. There was a significant interaction between coach role and trial ($F_{(1, 15)} = 4.7, P<0.05$), although no differences were found at a post hoc level.

4.4.3 Time spent in heart rate zones

There was no significant main effect of trial ($P>0.05$) in any HR zone, though the effect of player role was significant, with players spending a greater amount of time attacking in zone 1 compared to defending (62.0 ± 31.5 and $48.4 \pm 31.3\%$ of total time respectively, $F_{(1,15)} = 8.76, P<0.05$). Player role did not have an effect in zone 2 ($F_{(1, 15)} = 4.1, P>0.05$), 3 ($F_{(1, 15)} = 0.7, P>0.05$), and 4 ($F_{(1, 15)} = 1.4, P>0.05$; Figure 4.3). The effect of coach role was significant only for zone 4 ($F_{(1,15)} = 7.71, P<0.05$), with the amount of time being greater with coach encouragement than without ($7.4 \pm 4.9\%$ versus $6.3 \pm 3.8\%$ of total time; Figure 4.4). The effect of age in each HR zone was significant (Figure 4.5), with U13 players spending more time in zone 1 compared to the U15 players ($68.6\% \pm 22.5$ and $43.3 \pm 34.6\%$ of total time, respectively; $F_{(1, 15)} = 7.91, P<0.05$), and the U15 players spending more time in the three lower zones than the U13 players (zone 2, $F_{(1, 15)} = 5.56, P<0.05$; zone 3, $F_{(1, 15)} = 7.26, P<0.05$; and zone 4, $F_{(1, 15)} = 4.71, P<0.05$; respectively).

There were some significant interactions, which were not significant when tested at post hoc level (between HRpeak and coach role and trial, time spent in HR zones 1 and 3 and coach role and trial and time spent in coach role and player role in zone 2). Although the use of Bonferroni post-hoc analyses has been suggested to be 'conservative' in terms of the type 1 error rate (Field, 2005), it can be assumed the differences were small and therefore not significant.

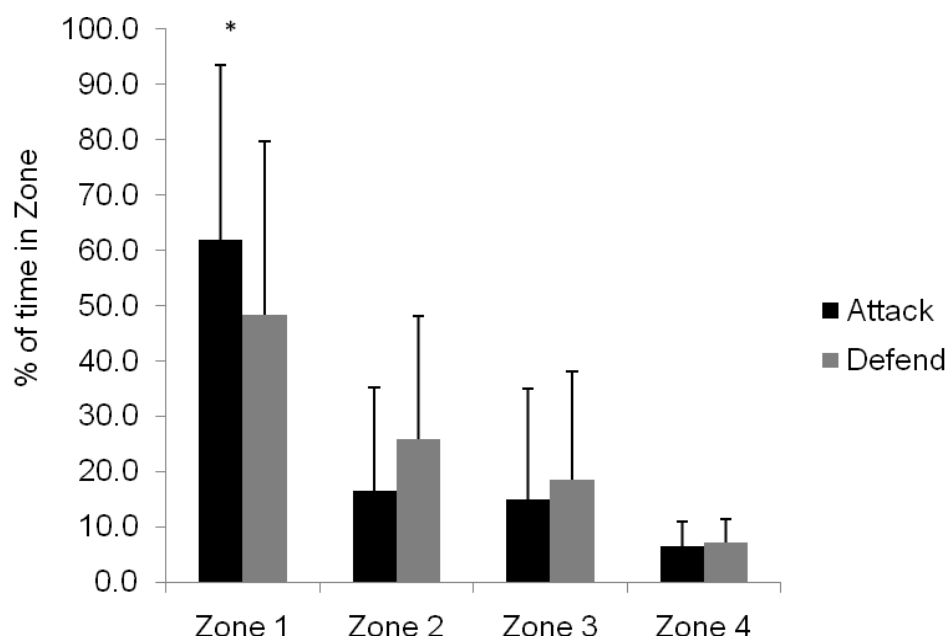


Figure 4.3: Mean \pm SD of percentage of time attacking and defending in HR zones (trials combined). *Significant difference between player role ($P < 0.05$).

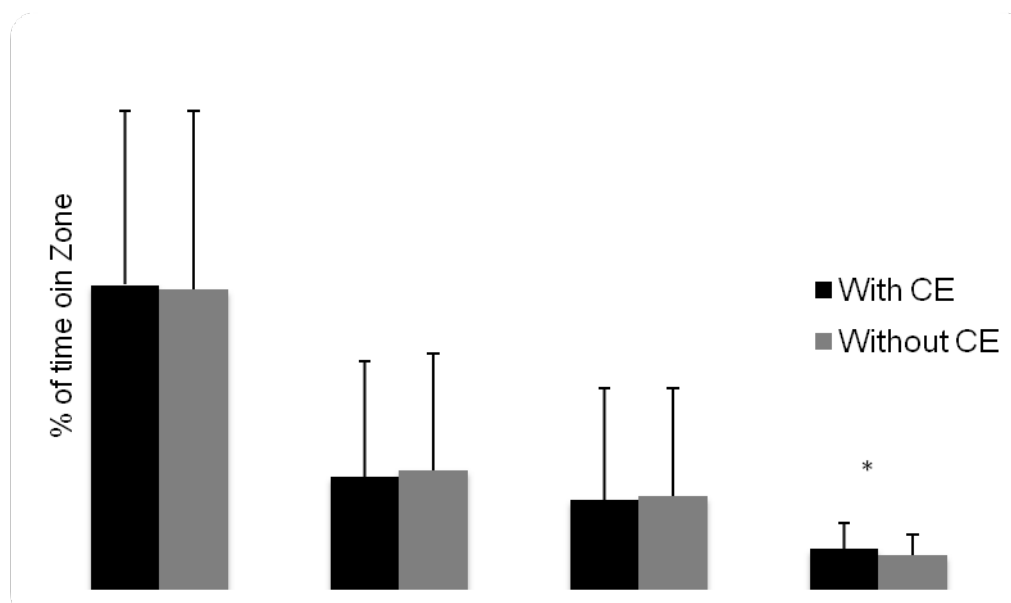


Figure 4.4: Mean \pm SD of percentage of time in HR zones of SSGs with and without coach encouragement (trials combined). *Significant difference between coach role ($P < 0.05$). With CE = with coach encouragement, Without CE = without coach encouragement

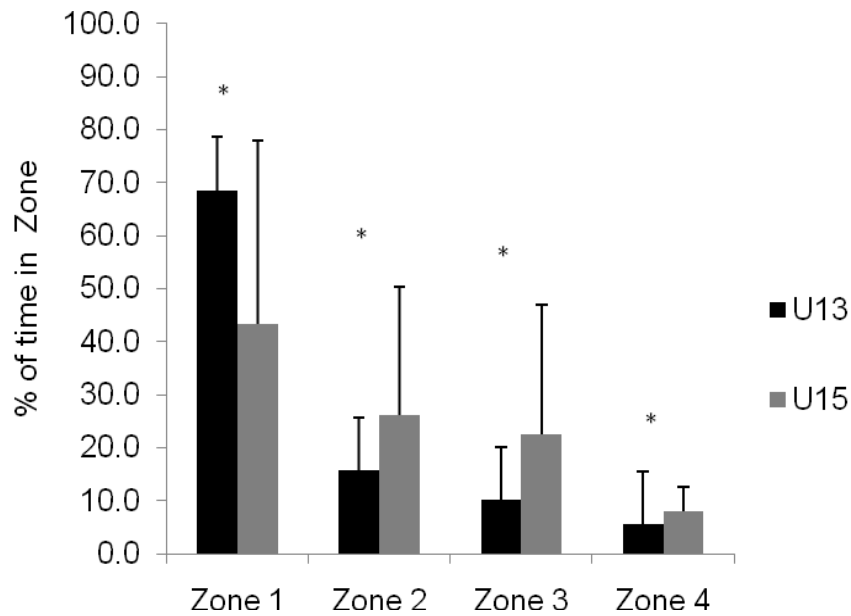


Figure 4.5: Mean \pm SD of percentage of time in HR zones for each age group (Trials combined). *Significant difference between age groups ($P < 0.01$).

4.4.4 Reliability of game actions

Percentage difference statistics showed varying repeatability of game actions from trial 1 to trial 2, which generally revealed poor reproducibility of the game actions undertaken within the SSGs (Table 4.10). This variability ranged from 0 to 400% between trials (disregarding if the differences were negative or positive). Moreover, there were no obvious patterns in repeatability inflicted by playing age or coach encouragement. The repeatability between tries scored was large and ranged from 0-150% difference. Likewise, the percentage difference scores for errors made and set completion ranged from 20-400% and 0-200%, respectively. Percentage difference of successful and successful touches ranged from 10.3-69.2% and 0.0-59.1%, respectively. Percentage difference of successful and unsuccessful passes ranged from 5.6-59.1% and 0.0-150.0%, respectively. The percentage errors of attacking runs got larger as the run increased in phases from dummy run (0.0%-60.0%), hit up (8.3-83.3%) to pass plays (0.0-120.0%).

Table 4.10 Percentage difference of game action frequencies (trial 2 difference from trial 1, %)

	Game 1	Game 2	Game 3	Game 4	Game 8	Game 7	Game 6	Game 5
	U13 With	U13 With	U13 Without	U13 Without	U15 With	U15 With	U15 Without	U15 Without
Tries	0.0	0.0	-100.0	150.0	-100.0	0.0	-100.0	-100.0
Error	66.7	50.0	125.0	100.0	-28.6	25.0	-20.0	400.0
Comp Set	0.0	50.0	0.0	-66.7	66.7	-33.3	200.0	-60.0
Suc Touch	-31.4	-14.3	-13.3	-53.8	69.2	-14.6	12.9	-10.3
Unsuc touch	-33.3	-45.5	33.3	0.0	-60.0	25.0	-11.1	-53.8
Suc Pass	5.6	-30.0	0.0	33.3	-16.7	-59.1	-20.0	-26.7
Unsuc Pass	0.0	0.0	100.0	50.0	-25.0	50.0	0.0	150.0
Dummy Run	-41.7	-9.1	18.2	-50.0	35.7	60.0	29.4	0.0
Hit Up	-38.5	-76.9	-58.3	25.0	8.3	-40.0	-15.4	83.3
Pass Play	80.0	120.0	40.0	20.0	-33.3	-50.0	0.0	-50.0

With = with coach encouragement. Without = without coach encouragement. Comp Set.Suc Touch = successful touch. Unsuc Touch – unsuccessful touch. Suc Pass = successful pass. Unsuc Pass = unsuccessful pass.

4.4.5 Frequency of Game actions

On average with the trials combined, the four-minute SSGs elicited 0.5-2.5 tries, 3.3-5.3 errors and 1-5-3.8 completed sets of four plays. Moreover, players performed 23.5-36.5 and 4.0-9.0 successful and unsuccessful touches, respectively. Attacking play created 11.0-18.8 successful passes and 3.5-8.0 unsuccessful passes. In addition, there were 10.2-19.8 dummy runs, 8.8-10.3 hit ups and 2.5-7.5 pass plays (Table 4.11).

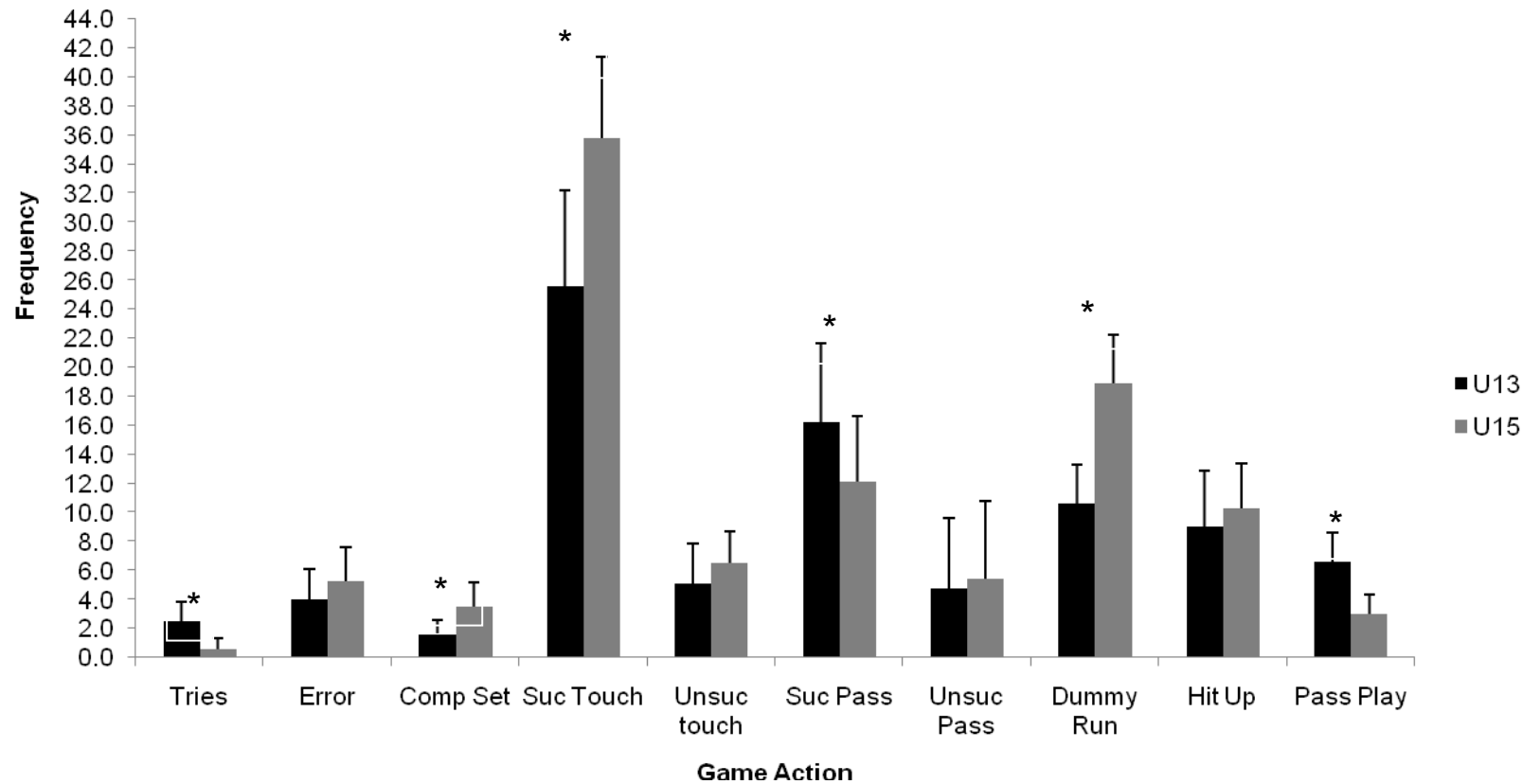
Coach encouragement did not have an influence on the majority of game actions. The younger players performed more successful touches (27.8 ± 5.2 versus 23.5 ± 7.9) than the older players in the SSGs with coach encouragement. In addition, the younger players obtained less successful passes (13.8 ± 8.3 versus 18.8 ± 2.5) in the presence of coach encouragement. The older junior players obtained fewer unsuccessful touches (4.0 ± 1.4 versus 9.0 ± 2.9) but more unsuccessful passes in the SSGs with coach encouragement (Table 4.11).

Playing age had a greater effect on the frequency and success rate of game actions, regardless of whether coach encouragement was included within the SSGs (Figure 4.6). The U13s scored more tries on average (2.5 ± 1.1 versus 0.6 ± 0.3) but obtained less completed sets (1.6 ± 0.0 versus 3.5 ± 0.6) than the U15 players. Furthermore, the younger players performed less successful touches (25.6 ± 1.9 versus 35.8 ± 3.3) but more successful passes (21.3 ± 0.0 versus 17.4 ± 3.1) than the older players. In addition, the older players performed more dummy runs (18.9 ± 1.8 versus 10.6 ± 0.7) but less pass plays (3.0 ± 0.5 versus 6.6 ± 1.4) than the younger players.

Table 4.11: Game action frequencies (trials combined)

Game Action	With Coach Encouragement				Without Coach Encouragement			
	Mean \pm SD	U13 Median \pm 95% CL	Mean \pm SD	U15 Median \pm 95% CL	Mean \pm SD	U13 Median \pm 95% CL	Mean \pm SD	U15 Median \pm 95% CL
Tries	2.5 \pm 0.6	2.5 \pm 2.1-2.9	0.8 \pm 1.0	0.5 \pm 1.8-3.2	2.5 \pm 2.1	2.5 \pm 1.0-4.0	0.5 \pm 0.6	0.5 \pm 2.1-2.9
Error	3.3 \pm 1.3	3.0 \pm 2.4-4.1	5.3 \pm 1.3	5.0 \pm 2.4-4.1	4.8 \pm 3.0	4.0 \pm 1.2-5.3	5.3 \pm 3.4	4.5 \pm 0.9-5.6
Comp Set	1.8 \pm 1.0	1.5 \pm 1.1-2.4	3.3 \pm 1.3	3.0 \pm 0.9-2.6	1.5 \pm 1.0	1.0 \pm 1.1-2.5	3.8 \pm 2.1	3.5 \pm 0.3-3.2
Suc Touch	27.8 \pm 5.2	26.0 \pm 24.1-31.4	36.5 \pm 7.9	38.0 \pm 22.0-33.3	23.5 \pm 7.9	26.0 \pm 22.2-33.3	35.0 \pm 3.3	35.0 \pm 25.5-30.0
Unsuc Touch	5.5 \pm 4.0	4.5 \pm 2.7-8.3	4.0 \pm 1.4	4.5 \pm 4.5-6.5	4.8 \pm 1.5	5.0 \pm 4.5-6.6	9.0 \pm 2.9	8.5 \pm 3.4-7.6
Suc Pass	13.8 \pm 8.3	16.5 \pm 18.1-22.9	11.0 \pm 7.1	12.0 \pm 8.8-18.7	18.8 \pm 2.5	20.0 \pm 12.0-15.5	13.3 \pm 2.1	13.5 \pm 12.3-15.2
Unsuc Pass	6.0 \pm 8.0	2.0 \pm 0.4-11.6	8.0 \pm 9.3	3.5 \pm -0.5-12.5	3.5 \pm 1.7	3.0 \pm 4.8-7.2	2.8 \pm 1.5	2.0 \pm 5.0-7.1
Dummy Run	10.2 \pm 2.2	10.5 \pm 8.5-11.5	18.0 \pm 4.5	17.0 \pm 6.8-13.2	11.3 \pm 3.1	12 \pm 7.8-12.2	19.8 \pm 2.1	20.0 \pm 8.6-11.4
Hit Up	9.3 \pm 4.8	10.5 \pm 2.9-12.6	10.3 \pm 3.1	11.0 \pm 7.1-11.4	8.8 \pm 3.0	9.0 \pm 7.2-11.3	10.3 \pm 3.0	11.0 \pm 7.2-11.3
Pass Play	7.5 \pm 3.0	7.0 \pm 5.4-9.6	3.5 \pm 1.7	3.0 \pm 6.3-8.7	5.8 \pm 1.0	5.5 \pm 6.8-8.2	2.5 \pm 1.0	2.0 \pm 6.8-8.2

Comp set = completed set. Suc Touch = successful touch. Unsuc Touch – unsuccessful touch. Suc Pass = successful pass. Unsuc Pass = unsuccessful pass.



Suc Touch = successful touch. Unsuc Touch – unsuccessful touch. Suc Pass = successful pass. Unsuc Pass = unsuccessful pass. * = difference between age groups.

Figure 4.6: Mean \pm SD of game action frequencies (trials combined and SSGs with and without coach encouragement combined).

4.4 Discussion

From a coach's perspective, it is imperative that SSGs can stimulate physiological responses that are reproducible in order that they can use SSGs as part of a periodised training programme. Such consistency needs to be achieved by most, if not all, players and the extent of this is best reflected in the random error component of the 95% LoA statistic. The LoA for both SSG peak and average HR values were relatively wide in both attacking and defending roles in SSGs with and without coach encouragement, across both age groups, and overall with age group scores combined, suggesting poor repeatability over the two trials. This judgement is qualified on the basis that, for example, an U15 player defending in a SSG with coach encouragement yielding an average HR of 80% HR_{max} in trial 1 could have been, in a worse case scenario, as high as 97.4% or as low as 70.1% in trial 2. The reliability analyses of the mean HR responses to SSGs conducted in this Chapter are in agreement with Rampinini et al.'s (2007) study, in which moderate-poor reliability of soccer SSGs was reported, but contrasts other SSG studies which have reported SSGs provide a reliable aerobic conditioning stimulus (Little and Williams, 2006; Tessitore et al., 2006; Little and Williams, 2007; Hill-Haas et al. 2008). However, direct comparisons to previous studies are problematic due to SSG rules not being described (Rampinini et al., 2007; Hill-Haas et al. 2008), differences in SSG format (Little and Williams, 2006; Hill-Haas et al. 2008) and the LoA technique not being utilised (Hill-Haas et al., 2008), which is the recommended method of assessing reliability (Atkinson and Nevill, 1998).

The LoA for percentage of time spent in HR zones were also wide, with differences between trials being as high or low as 95.8, 69.8 and 74.7% in the worse case scenarios in zones 1, 2 and 3, respectively. The LoA for percentage of time spent in HR zone 4 were narrower, although these are still quite wide in terms of test-retest repeatability ($\pm 17.3\%$ in the worse case scenario). Thus, collectively, the HR reliability statistics suggest poor repeatability between trials. Moreover, the time spent in higher HR zones (1, 2 and 3) is less repeatable on a test-retest basis than time spent in a

moderate intensity zone (zone 4). However, to date, there has been no other comparable research and further research is required in this area.

Interestingly, the reliability findings from Chapter 4 contrast with the findings from Chapter 3, which reported good repeatability of HR intensity between SSG trials. As players in both studies were from similar playing levels, possessed similar fitness levels and were all habituated to the use of SSGs, the differences in reliability between the SSGs conducted in Chapters 3 and 4 are most likely due to differences in the SSG rules adopted. Despite games lasting for the same duration, being officiated by a qualified coach and a two-handed touch constituting a tackle, the restart method from each SSG was different, with tap and PTB restart rules in the SSGs in Chapters 3 and 4, respectively. Although in both game conditions all players were encouraged to restart play immediately, the tap restart could have produced a consistently faster restart as players could remain on their feet to restart play. Moreover, PTB speed has been previously suggested to affect the effectiveness of the dummy half run (Eaves and Evers, 2007), which could therefore effect the intensity and reproducibility of demands within SSGs that include a PTB restart. In addition, the SSGs incorporated in Chapter 3 were a basic 'offside touch' game, commonly used in RL conditioning, whereas the SSGs examined in Chapter 4 were an onside SSG, more realistic to full match play. A recent study within RL specific SSGs has reported offside rules to elicit greater physiological and technical demands than onside rules (Gabbett, 2010). Thus, offside and onside rules within RL specific SSGs may affect the reproducibility of HR responses.

Percentage difference statistics showed varying repeatability of game actions from trial 1 to trial 2, which generally revealed poor reproducibility of the game actions undertaken within the SSGs. Moreover, there were no obvious patterns in repeatability inflicted by playing age or coach encouragement, therefore suggesting that playing age and coach encouragement do not affect the repeatability of game actions within RL specific SSGs. The repeatability between the key attacking and defending game actions was narrower but still showed poor reliability in most cases. Nonetheless, the

percentage differences became larger when the key game actions were examined in further scrutiny in relation to skill success rate and type of attacking run. Moreover, the percentage error of attacking runs got larger as the run increased in phases from dummy run, hit up to pass plays. These data suggest that repeatability of RL specific skills within SSGs worsens as the skill becomes more complex or examined in further detail in terms of success rate. Further investigation is required into this speculative finding. Moreover, differences within game action frequencies between trials could affect SSG HR demands and therefore the repeatability of the HR responses. It is therefore not surprising that both game action and HR demands are unreliable within this Chapter's results.

Notwithstanding the poor HR reliability, one of the key functions of SSGs is to act as a stimulus for aerobic development. As all HR intensities were above 85%, and some above 90% HRmax, the function of the SSGs still remained applicable as a conditioning tool. Moreover, the findings have provided innovative investigation into the demands of both player and coach role in RL specific SSGs. In addition, aside from the poor game action reliability, SSGs allow specific game skills to be assessed under pressurised simulated scenarios. Nevertheless, the technical demands of rugby specific SSGs had previously not been examined. Thus, test-retest repeatability of game actions within rugby specific SSGs had yet to be determined, so provided innovative findings.

The SSGs performed within this study elicited mean HR intensities above 85% HRmax, which are considered to be both 'high' in competitive junior RL (Estell et al., 1996) and above match intensity (Coutts et al., 2003). The younger junior players and the condition of attacking play (age groups combined) elicited an average SSG HR intensity corresponding to zone 1 (above 90% HRmax), demonstrating that the RL specific SSGs used in this study are able to elicit the recommended SSG HR intensity for aerobic conditioning (Helgerud et al., 2001; Hoff et al., 2002). Furthermore, all players had the greatest percentage of time in zone 1 above 90% HRmax and the least amount of time in the lowest HR zone, zone 4. However, older

junior players and the condition of defending play yielded an average SSG intensity falling within HR zone 2 (85-89.9% HRmax), suggesting that playing age and player role can have a potential mediating effect on SSG intensity.

All players spent more time attacking in zone 1 (>90% HRmax), compared to defending whereas, although not significantly different, players spent more time defending in comparison to attacking in zones 2, 3 and 4, respectively. In addition, the average HR responses during attacking play were significantly higher than defending play. This finding is in conflict with the demands of full contact competitive match play where the WRR during defending is significantly higher than attacking in elite senior RL players (Sykes et al., 2009). It is likely that the rules of the SSGs in this study contributed to the differences in intensity obtained in attacking and defending play when compared to full match play; namely the non-contact defence and the reduced defensive line (5 m retreat following the completion of a touch before recommencing play as opposed to the 10 m retreat stipulated in full match play). However, although studies have documented that the physical contact during competitive RL adds to the high-intensity intermittent nature of the game (Gabbett, 2008b; Gabbett et al., 2008), the physiological demands of tackling or the differences between contact and non-contact conditioning rugby SSGs have yet to be investigated. The findings presented here are the first to demonstrate a difference in the intensity, and therefore physiological stimulus, between attacking and defending roles during rugby SSGs. Consequently, when using SSGs coaches should be cognisant of the importance of player role and its effect on the physiological stress imposed on the player.

The U13 players obtained a greater average HR than the U15 players during the SSGs and more time in HR zone 1 compared to the U15 players, whereas the U15 players spent a greater amount of time in lower HR zones than the U13 players. This finding is difficult to explain as the U13 players performed less dummy runs than the U15 players, although the younger players were found to perform a greater number of successful passes and

pass plays than the older players. A possible explanation for this finding could be that although the older junior players completed more dummy runs (as a single movement by one player taking the ball forward), the younger players may have performed more overall running due to the increased number of successful passes resulting in more movement simultaneously by all players. Further time-motion data using global positioning systems (GPS) could confirm this speculative suggestion. Nonetheless, the differences in technical demands suggest differences in playing styles between groups, with younger players adopting a basic passing game and older players carrying out a more attacking running game with more dummy runs and possibly gaining more ground. The older players also completed more successful touches (tackles) than the younger players, again suggesting a higher number of attacking runs into the defensive line in this group. Collectively the differences in skill and technical approaches adopted between age groups might explain the higher HR response observed in younger players during an onside SSG.

Younger players performed a greater frequency of tries whereas the older players obtained a greater number of completed sets. This difference again reflects the suggested different styles in play with the younger players eliciting a greater number of passes, creating space for passes and tries whereas the older players who obtained a greater amount of attacking runs and dummy runs, taking the ball into the defensive line, consequently scored less tries and more completed sets. Moreover, the combined number of tries scored, errors made and completed sets were similar in both age group SSGs (7.6-9.9), thus, the SSGs would have elicited a similar amount of HR intensity in terms of resetting after a try, error or end of set.

There were no differences in average and peak HR intensity performed between SSGs with and without coach encouragement. Likewise, the presence of coach encouragement with SSGs had no effect on the time players spent in HR zones 1, 2 and 3. Conversely, there was a significant difference within HR zone 4, although this difference was only 0.9% of total time. Ultimately, the findings suggest that coach encouragement had no

influence, negative or positive, on SSG playing intensity. This finding conflicts with the results of a previous soccer SSG study which reported an increase in exercise intensity in soccer SSGs with coach encouragement (88.7% HRmax) compared to SSGs without (86.5% HRmax; Rampinini et al., 2007). Likewise, previous resistance training studies have found the presence of a coach increased training performance due to increases in training intensity, attendance, volume, more frequent use of maximum efforts and psychological factors of external motivation and increased competitiveness (Mazzetti et al., 2000; Coutts, 2004; Gentil and Bottaro, 2010). Differences in the effects of coach involvement could be attributed to players in this study being well habituated to the format and intensity of SSG conditioning, as well as them playing at a high level. All players were previously habituated to similar SSG conditioning in weekly training sessions across a three-month period prior to data collection. A 30 minute SSG session was carried out in the end of a weekly hour session in which the high-intensity format of four times four-minute games and three minutes active recovery was used throughout and players were verbally encouraged to achieve a high exercise intensity. However, in the only paper which has quantified the physiological responses to soccer SSGs with and without coach encouragement; Rampinini et al. (2007) did not report if their participants had undergone any habituation prior to participating in the SSGs in their study.

4.6 Conclusions and practical applications

The present study is the first to report the HR responses, repeatability of these responses and the technical demands to both attacking and defending roles in RL specific SSGs for two discrete junior age groups. The effects of coach encouragement on these demands was also analysed to enable coaches to optimise conditioning through SSGs. The findings demonstrate that SSGs can elicit high HR responses adequate for aerobic conditioning. This study's findings are the first to demonstrate a difference in HR intensity between player roles within RL SSGs, as attacking play elicited a greater average SSG intensity and a greater amount of time in a high-intensity HR

zone than defending play (in contrast to full RL match play). Such observations are possibly due to the SSGs not employing contact defence situations and incorporating a reduced defensive line (5 m retreat following the completion of a touch before recommencing play as opposed to the 10 m retreat stipulated in full match play).

Discrepancies were also reported between playing age and SSG intensity and performance with the younger players eliciting a greater average SSG intensity, a greater amount of time in high-intensity and less time in lower HR intensities than the older junior players. These differences in HR responses can possibly be explained by differences found in the technical demands performed, as younger junior players performed a greater volume of successful passes than the older players, possibly creating more continuous movement by all players whereas the older players performed a greater volume of dummy runs, involving more single player movements. Therefore, differences in playing style were evident between the age groups.

The addition of coach encouragement had no effect on the HR responses or volume of game actions carried out. This finding could reveal the importance of habituation to SSG training as a HIT format, allowing players to perform independently following coaches instructions from previous SSG training sessions. The HR and technical demands elicited from the SSGs conducted within this study demonstrated poor reliability. Therefore, further investigation into the repeatability of RL SSG demands is warranted.

The practical applications from these findings are that coaches need to be aware of the potential mediating effects that player role and age have on SSG intensity and performance. Specifically, that attacking play can elicit a greater physiological stimulus than defending in non-contact SSGs. Therefore, coaches may need to adapt the defensive rules within non-contact SSGs to ensure an adequate intensity is achieved for aerobic development. In addition, coaches need to be aware that players of different ages may adopt different playing styles to an identical SSG, which therefore alters the SSG technical and physiological demands.

Chapter 5 Conclusions

5.1 Main Findings

5.1.1 Factors influencing small-sided games

The SSGs performed in both studies of this thesis elicited mean heart rate (HR) intensities above 85% HRmax, which are considered to be both 'high' in competitive junior RL (Estell et al., 1996) and above match intensity (Coutts et al., 2003). In addition, players spent the greatest amount of time in the highest intensity zone (zone 1; $\geq 90\%$ HRmax) and the least amount of time in the lowest intensity zone (zone 4; $\leq 74.9\%$ HRmax) during SSGs (Chapter 4). However, while the SSGs from both studies obtained the target intensity of 90% HRmax to achieve aerobic adaptations, HR appeared to be dependent upon player number (Chapter 3), player role (Chapter 4) and player age (Chapters 3 and 4).

In Chapter 3, which examined the effects of altering both player number (4v4 and 6v6) and playing area size (15x25 m, 20x30 m, and 25x35 m), the mean HR responses during the 4v4 SSGs were consistently higher than those of the 6v6 SSGs, albeit among the older junior players only. These differences were explained possibly due to a greater number of ball contacts and overall individual involvement during the 4v4 condition. Interestingly, playing area size revealed no effect on mean HR, suggesting that playing area size does not affect the HR demands of RL SSGs in young players.

In Chapter 4, attacking play was found to elicit a greater HR intensity and elicit a greater amount of time in a high-intensity HR zone than defending. This is in contrast to defending, where players spent a greater amount of time in lower HR zones. These findings are in conflict with the demands of competitive match play, and it is likely that the rules of the SSGs in this study contributed to the observed differences; namely the use of non-contact defence (i.e. touch tackle) and a reduced defensive line (5 m) in comparison to the defensive retreat stipulated in full match play (10 m).

There were limited differences in the mean HR, peak HR or technical demands of the SSGs performed with or without coach encouragement. Speculatively, the differences between the findings from Chapter 4 and previous findings (e.g. Rampinini et al., 2007) were attributed to players being well habituated to the format and intensity of SSG conditioning, as well as being of a high playing standard.

To determine if different training responses were apparent between different junior age groups, identical procedures were carried out in two different junior age groups (U13 and U16; Chapter 3) and (U13 and U15; Chapter 4). Chapter 3 found older junior players elicited a higher HR response in 4v4 SSGs in comparison to 6v6 SSGs, whereas there were no differences in player number and HR intensity between the younger players. These differences were attributed to the potential development and technical differences between the two age groups; namely that younger players self-restricted the area in which they work due to their awareness of extra-personal space being less developed than the older players.

In contrast, the U13 players obtained a higher HR intensity than the U15 players in the SSGs conducted in Chapter 4, despite performing less attacking runs and touches but more passes. Moreover, younger players performed a greater frequency of tries whereas the older players obtained a greater number of completed sets, although this difference was in equal measures and was therefore suggested to balance HR intensity between the age groups in relation to resetting runs after a try, error or end of set. A possible explanation of the aforementioned technical differences and HR intensities between age groups could be that the younger players may have carried out a greater amount of running overall due to the increased number of successful passes, pass plays and tries, resulting in more simultaneous player movement creating space to pass and score tries. This is in comparison to the older junior players who may have completed less overall running due to carrying out less passes, more dummy runs and touches (due to single players movement taking the ball forward in each play in an attacking the line style of play).

5.1.2 The reliability of small-sided games

The repeatability of SSG demands is important so that coaches can be confident in the ability of SSGs to provide a consistent aerobic training stimulus. Differences in the reliability of the HR demands between Chapter 3 and 4, which were found to be good and poor reliability, respectively, were speculated to be due to differences in SSG rules. The tap restart (Chapter 3) would have produced a faster restart as players could remain on their feet to restart play than the PTB restart (Chapter 4), which could have been more consistent in controlling the speed and therefore SSG intensity. Furthermore, the SSGs incorporated in Chapter 3 were a basic 'offside touch' game, commonly used in RL conditioning, whereas the SSGs examined in Chapter 4 incorporated an onside rule, more realistic to full match play. Thus, offside SSGs may elicit more reproducible HR responses than onside SSGs.

The game actions examined within Chapter 4 demonstrated poor test-retest repeatability, which worsened with increasing skill complexity and when examined in further detail in terms of success rate. The finding that both HR and game action data had poor reliability is likely to be integrated, with differences in game action frequencies between trials affecting the HR demands and therefore the repeatability of the HR responses. However, further investigation into this speculative finding is warranted.

5.2 Practical applications

The findings from this thesis demonstrate that RL SSGs can elicit exercise intensities appropriate for aerobic conditioning providing certain variables are given due consideration. In particular, coaches should be cognisant of the potential effect that player number might impose upon SSGs, and that SSGs with smaller group sizes are more effective when higher exercise intensities are required. However, such considerations might not stand for younger junior players, who might be more prone to restricting the area in which they play. Therefore coaches should ensure some game conditions are adapted to encourage greater movement when working with younger age groups. Coaches should also be aware of the potential mediating effect that player

role has on SSG intensity and performance, and that attacking play elicits a greater physiological stimulus than defending in non-contact SSGs. Therefore, coaches may need to adapt the defensive rules within non-contact SSGs to ensure an adequate intensity is achieved for aerobic development. Possible defensive rule adaptations could include extra running, an increased defensive retreat line or extra conditioning rules following each play such as a press up or sit up. In addition, coaches need to be aware that players of different ages may adopt different playing styles to an identical SSG, which therefore alters the SSG technical and physiological demands. Furthermore, manipulating SSG rules can affect the reproducibility of HR responses and therefore the physiological stimulus, and simple offside SSGs may be more reproducible than more complex onside SSGs.

Finally, coaches may need to be aware of the level of verbal encouragement required in high level players who have previously participated in a SSG habituation period in which a HIT format was commonly employed. Anecdotally, players seemed to motivate each other to work hard, reset quickly and alter individual position in relation to team mates and the opposition regardless of coach involvement, although this was not assessed. Based on the Teaching Games for Understanding (TGfU) model, this scenario created where coach encouragement was not required, could possibly further heighten learning through increased decision making abilities. Furthermore, these findings would suggest that coaches need to be aware of the importance of habituation to SSG training as a HIT method in achieving intensities appropriate for aerobic development and the importance of SSG delivery to achieve a high-intensity. Methods to increase SSG intensity within the SSG habituation phase of the studies in this thesis included verbally encouraging players to perform a quick restart after each play and ensuring extra rugby balls were placed on both try lines. In addition, coaches either side of the sidelines quickly reintroduced a ball when one went out of play. Games were refereed with a referee keeping up with play either as a defensive line (Chapter 4) or from within the game (Chapter 3) and coaches encouraged fast movement and play. Players brought their water bottles to the side of the pitch so they could quickly get a drink in the

recovery periods before commencing active recovery which was a low-intensity exercise conducted at a very light jog (line passing).

The initial stage of this thesis included several meetings and a need analysis process with the Rugby Football League (RFL) who provided financial assistance towards the project to provide SSG coach education material. Pilot work included monitoring existing SSGs within a Super League Scholarship across a period of 6 months. This period involved numerous coach meetings and coach education sessions in developing the SSG format and rules with the aims of eliciting both conditioning and skill development elements. I have also provided SSG educational and practical sessions on the junior England pathway and with the England Women's national squads. From an academic viewpoint, the research has been presented at sports science conferences (British Association of Sport and Exercise Sciences, European College of Sport Science), a rugby league specific sport science conference (Rugby Football League Sport Science, Medicine and Performance Conference) and has produced a research paper titled 'Heart rate responses to small-sided games among elite junior rugby league players'. In addition, the research has provided the RFL with coach education material including an online educational article titled 'The benefits of SSG conditioning', and an online resource, which all licensed coaches in England can access. The online resource consisted of some introductory information on the benefits of SSG conditioning, how to achieve suitable intensities for aerobic development and a series of SSGs, based on the principle findings from this thesis and SSG pilot work. Collectively, the application of the research has reached a wide range of coaches and players. As a result, SSGs are now a frequent part of rugby league conditioning. Further, with the online resource, the research has the potential to further amplify the knowledge and application of SSG conditioning and transfer into other team sports conditioning.

5.3 Limitations

5.3.1 Methods of monitoring small-sided games

The main limitation within this thesis is that additional methods of monitoring exercise intensity could have been employed, such as ratings of perceived exertion (RPE), HR-VO₂ relationships and movement demand analysis. Whilst the most common method of monitoring the SSG intensity is HR, a few SSG studies have monitored perceptual demands through obtaining RPE (Aroso et al., 2004; Rampinini et al., 2007; Coutts et al., 2009; Casamichana and Castellano, 2010; Fanchini et al., 2011). However, RPE was not monitored in this thesis due to the subjective nature of self-perception and the potential influence of other participants when recording values in a group scenario. Moreover, although RPE has recently been found to be moderately correlated to %HRmax and blood lactate within soccer SSGs (Coutts et al., 2009), the reliability of RPE within SSGs has been questioned, as poor RPE test-retest values of 15-58% (expressed as a percentage of the mean) have been reported within soccer SSGs in comparison to HR values (5-14%) (Rampinini et al., 2007). In addition, analysing the HR-VO₂ linearity within SSGs would have been of interest. However, this was not planned prior to data collection and consequently VO₂ was not recorded throughout the maximal treadmill test and only VO_{2max} was recorded. Thus, it was not possible to plot HR-VO₂ relationships.

A further limitation within this thesis is that it was not possible to access global positioning system technology (GPS). Although the reliability of GPS in high-intensity and intermittent sports has recently been questioned (Coutts and Duffield, 2010), GPS analysis has been utilised in recent soccer SSG studies (Barnes et al., 2008; Hill-Hass et al., 2008; Hill-Hass et al., 2009a; Gabbett et al., 2010; Casamichana and Castellano, 2010). GPS could have provided an accurate and objective analysis of the movement demands within the SSGs, such as actual speed, accelerations, decelerations and distances covered within particular speed zones. Furthermore, the speculative findings provided within Chapter 3 that younger junior players may self regulate their work area could have been examined in detail.

However, it was not possible to explore this speculation, as GPS analysis was not included. In addition, the SSGs in Chapter 3 were not video recorded and therefore, a technical analysis was not conducted. This would have provided interesting findings in integrating game action and HR reliability within the SSGs in Chapter 4, which were found to be both unreliable in comparison to the SSGs examined in Chapter 3, which found HR demands to be reliable but no skills were analysed.

5.3.2 Quantification of small-sided game habituation

A further limitation to this study is that it was not possible to quantify the habituation period used, as in both studies a variety of SSGs were carried out in conjunction with a technical and resistance training programme over a period of three months. It is therefore unclear how many sessions are required to achieve an appropriate and consistent training response through SSG conditioning. Furthermore, the finding that coach encouragement had limited impact on the HR or technical demands of SSGs (Chapter 4) was attributed to players being of a high playing level and being habituated to SSGs. However, this suggestion was speculative and it was not possible to compare findings with players who had received no prior SSG habituation.

5.3.3 Participant training status

Both studies in this thesis examined the SSG demands in Scholarship players from an English Superleague team, thus the players can be classified as high-level. Thus, it is difficult to extrapolate findings to elite and recreational players. In addition, similar junior age groups were examined in both studies and, it is unclear if similar responses are observed in junior age groups not examined in this thesis.

5.4 Future directions

5.4.1 Monitoring small-sided games with global positioning systems

The use of GPS technology is relatively new within team sports; however, analysis in RL competition has only recently been sanctioned due to

concerns over utilising GPS within contact sports. In addition, Coutts and Duffield (2009) have questioned the validity and reliability of GPS analysis in both intermittent and high-intensity sports. Therefore, there have been few studies determining RL competition and training demands through GPS analysis. Further investigation using GPS technology would heighten the knowledge of competition and training movement demands in terms of distances covered, time spent in speed zones and frequency of sprints. Moreover, some of the findings from this thesis could be further investigated and clarified using GPS analysis, such as the differences in movement demands and altering player number and player role (attacking versus defending play). In addition, test-retest reliability of SSG movement demands could be explored more accurately (removing error through the subjective analysis of computer notation). Finally, the demands of contact situations could possibly be examined through GPS accelerometry technology.

5.4.2 Rugby league small-sided game conditioning programmes

Small-sided games have been introduced as part of specific conditioning programmes in RL (Gabbett, 2005a; 2005b; 2006a), soccer (Reilly and White, 2004; Chamari et al., 2005; Hill-Haas 2009b), volleyball (Gabbett et al., 2006d; Gabbett, 2008) and as a sole conditioning method alongside low intensity technical training in soccer (Impellizzeri et al., 2006; Rampinini et al., 2007a), rugby union (Gamble, 2004) and RL (Gabbett, 2006b). Conditioning programmes utilising SSGs have shown no change in $\dot{V}O_{2max}$ during pre-season (Hill-Haas et al., 2009b), in-season (Reilly and White, 2004) and towards the end of the season (Gabbett, 2005b). In contrast, increases in $\dot{V}O_{2max}$ during both pre-season (Gabbett, 2005a; 2005b; 2006a; 2008) and mid-season (Chamari et al., 2005) training phases have been reported. However, it is uncertain whether the physiological changes were achieved through SSG conditioning alone or in combination with other RL-specific training methods such as skill, speed, power and agility training. Therefore, future studies should examine the effects of RL SSG training programmes, both in isolation and as part of a resistance and technical programme. In addition, the comparison against a control group carrying out traditional aerobic conditioning methods or extra technical training would

determine any increases physiological measures due to SSG conditioning. Finally, the monitoring of physiological parameters such as speed, strength, agility and muscular power pre and post SSG training should be monitored to determine if there are any adverse effects on physiological parameters from SSG conditioning.

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Chapter 7

Appendices

Appendix 1A:

Study 1 Participant Information Sheet

Participant Information Sheet

You are being invited to participate in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the information carefully and ask if there is anything you would like further information about.

Thank you for reading this.

What is the purpose of the study?

The need for specific aerobic conditioning within rugby league is essential due to the high physiological demands of the game.

The aims of the study are to determine the physiological demands of small-sided games (SSGs) and devise the most effective SSGs for aerobic development based on the number of players and playing area size.

Why have I been chosen?

You have been chosen as you are a scholarship player of a Super League Rugby club.

Do I have to take part?

Participation in the study is your decision. If you decide to participate you will be asked to sign a consent form. You will be free to withdraw at any time without giving a reason.

What will happen to me if I take part?

A series of SSGs will be carried out in your usual skills training sessions. The SSGs will involve different numbers of players and different playing area sizes. Each participant will wear a heart rate monitor across their chest in order to assess the physiological stress and intensity of the SSGs. The SSGs will be filmed in order to carry out a movement and skills analysis.

Participants will also visit the exercise laboratory at the University of Chester and carry out a maximal treadmill run to exhaustion. A heart rate monitor will be worn to obtain maximal heart rate. Expired air will also be collected via a face mask to obtain maximal oxygen uptake ($\text{VO}_{2\text{max}}$, a measurement of aerobic performance).

What are the possible advantages and risks of taking part?

Assuming you are healthy to exercise there is no risk in taking part in this study.

What are the possible benefits of taking part?

By taking part, you will be assisting in the advancement of knowledge in aerobic development of rugby league players, resulting in the production of appropriate SSGs for aerobic development. Additionally, you will gain training information on aerobic training through the use of SSGs.

What if something goes wrong?

If you wish to complain or have any concerns about any aspects of the way you have been approached or treated during the course of the study, please contact Professor Sarah Andrew, Dean of the School of Applied and Health Sciences, University of Chester, Parkgate Road, Chester, CH1 4BJ, 01244 513055.

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence (but not otherwise), then you may have grounds for legal action but you may have to pay for this.

Will my taking part in the study be kept confidential?

All information collected about you during the course of the research will be kept confidential so that only the researchers carrying out the research and the Rugby Football League will have access to such information.

What will happen to the results of the research study?

The results of the study may be published. Any information included will not be identifiable to any specific participant. You are entitled to request a copy of your results of the study if you wish. The SSGs tapes will be destroyed after the study has been written up.

Who is organising and funding the research?

The department of Sport and Exercise Science at the University of Chester will be organising and carrying out the study with funding from the Rugby Football League.

Who may I contact for further information?

If you have any other questions regarding the study please do not hesitate to contact Chrissy Foster:

01244 513437
c.foster@chester.ac.uk

Thank you for your interest in this research.

Appendix 1B

Study 2 Participant Information Sheet

Participant Information Sheet

You are being invited to participate in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the information carefully and ask if there is anything you would like further information about.

Thank you for reading this.

What is the purpose of the study?

The need for specific aerobic conditioning within rugby league is essential due to the high physiological demands of the game.

This study follows on from previous work carried out by University of Chester. The aims of the study are to determine the physiological demands of attacking, defending and coaching within small-sided games (SSGs).

Why have I been chosen?

You have been chosen as you are a scholarship player of a Super League Rugby club.

Do I have to take part?

Participation in the study is your decision. If you decide to participate you will be asked to sign a consent form. You will be free to withdraw at any time without giving a reason.

What will happen to me if I take part?

A series of SSGs will be carried out in your skills training sessions. The SSGs will be non contact (two handed touch) and will involve attacking and defending duties. Each participant will wear a heart rate monitor across their chest in order to assess the physiological stress and intensity of the SSGs. The SSGs will be filmed in order to carry out a movement analysis.

Participants will also visit the exercise laboratory at the University of Chester and carry out an incremental treadmill run to exhaustion. A heart rate monitor will be worn to measure maximal heart rate. Expired air will also be collected via a face mask to measure maximal oxygen uptake ($\text{VO}_{2\text{max}}$, a measurement of aerobic performance).

What are the possible advantages and risks of taking part?

Assuming you are healthy to exercise there is no risk in taking part in this study.

What are the possible benefits of taking part?

By taking part, you will be assisting in the advancement of knowledge in aerobic conditioning of rugby league players, resulting in the production of appropriate SSGs for aerobic development. Additionally, you will gain training information on improving aerobic fitness through the use of SSGs.

What if something goes wrong?

If you wish to complain or have any concerns about any aspects of the way you have been approached or treated during the course of the study, please contact Professor Sarah Andrew, Dean of the School of Applied and Health Sciences, University of Chester, Parkgate Road, Chester, CH1 4BJ, 01244 513055.

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence (but not otherwise), then you may have grounds for legal action but you may have to pay for this.

Will my taking part in the study be kept confidential?

All information collected about you during the course of the research will be kept confidential so that only the researchers carrying out the research, the Rugby Football League and Warrington Wolves Scholarship coaches will have access to such information.

What will happen to the results of the research study?

The results of the study may be published. Any information included will not be identifiable to any specific participant. You are entitled to request a copy of your results of the study if you wish. The SSGs tapes will be destroyed after the study has been written up.

Who is organising and funding the research?

The Department of Sport and Exercise Science at the University of Chester will be organising and carrying out the study with funding from the Rugby Football League.

Who may I contact for further information?

If you have any other questions regarding the study please do not hesitate to contact Chrissy Foster:

01244 511849
c.foster@chester.ac.uk

Thank you for your interest in this research.

Appendix 2

MEDICAL QUESTIONNAIRE

(PLEASE NOTE THAT THIS INFORMATION WILL BE CONFIDENTIAL)

Name:..... DOB:..... Age:.....

Please answer these questions truthfully and completely. The purpose of this questionnaire is to ensure that you are fit and healthy enough to participate in this laboratory practical/research project.

- | | | |
|--|--------------------------|--------------------------|
| | Yes | No |
| 1. Have you in the past suffered from a serious illness or accident. | <input type="checkbox"/> | <input type="checkbox"/> |
| If Yes, please provide details | | |

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.....
.....

- | | | |
|---|--------------------------|--------------------------|
| | Yes | No |
| 2. Have you consulted your doctor the last 6 months | <input type="checkbox"/> | <input type="checkbox"/> |
| If Yes, please provide details | | |

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.....
.....
.....

3. Do you suffer, or have you suffered from:

	Yes	No
Asthma	<input type="checkbox"/>	<input type="checkbox"/>
Diabetes	<input type="checkbox"/>	<input type="checkbox"/>
Bronchitis	<input type="checkbox"/>	<input type="checkbox"/>
Epilepsy	<input type="checkbox"/>	<input type="checkbox"/>
High blood pressure	<input type="checkbox"/>	<input type="checkbox"/>

- | | | |
|---|--------------------------|--------------------------|
| | Yes | No |
| 4. Is there any history of heart disease in your family | <input type="checkbox"/> | <input type="checkbox"/> |

- | | | |
|--|--------------------------|--------------------------|
| | Yes | No |
| 5. Are you suffering from any infectious skin diseases, sores, wounds, or blood infections i.e., Hepatitis B, HIV, etc.? | <input type="checkbox"/> | <input type="checkbox"/> |
| If Yes, please provide brief details | | |

.....
.....

Yes **No**

- | | | |
|--|--------------------------|--------------------------|
| | <input type="checkbox"/> | <input type="checkbox"/> |
| 6. Are you currently taking any medication | | |
| If Yes, please provide details | | |

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.....
.....

7. Are you suffering from a disease that inhibits the sweating process Yes No
☐ ☐

8. Is there anything to your knowledge that may prevent you from Yes No
participating in the testing that has been outlined to you? ☐ ☐
If Yes, please provide details

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Persons will not be permitted to take part in any experimental testing if they:

- have a known history of medical disorders (i.e. hypertension, heart or lung disease)
- have a fever, suffer from fainting or dizzy spells
- are currently unable to train because of a joint or muscle injury
- have had any thermoregulatory disorder
- have gastrointestinal disorder
- have a history of infectious diseases (i.e. HIV or Hepatitis B)
- have, if pertinent to the study, a known history of rectal bleeding, anal fissures, haemorrhoids or any other similar rectal disorder.

My responses to the above questions are true to the best of my knowledge and I am assured that they will be held in the strictest confidence.

Name: (Participant)..... Date:.....

Signed (Participant/Parent/Guardian):

(delete as appropriate)

Name: (Researcher) Christine Foster

Date:.....

Signed (Researcher):

Appendix 3

Consent Form

I have read the Information Sheet for this study and understand the purpose of the study and all test procedures. I understand that I am free to request further information at any time.

By signing this form I confirm that:

- The purposes of the tests have been explained to me.
- I am satisfied that I understand the procedures involved.
- I agree to the filming of the games from which movement data will be analysed.
- The possible benefits and risks of the tests have been explained to me.
- Any questions which I have asked about the tests have been answered.
- I understand that during the testing, I have the right to ask further questions.
- The information which I have supplied to the University of Chester prior to taking part in these tests is true and accurate to the best of my knowledge and belief and that I must notify the researcher promptly of any changes to the information.
- I give permission for my testing information to be released to Warrington Wolves Rugby Football League and anonymously the Rugby Football League.
- I understand that my participation in the tests is voluntary and I am therefore at liberty to withdraw my involvement at any stage.

Signature of participant..... Date.....

Signature of parent/guardian..... Date.....

Appendix 4A

Study 1 ethical approval



University of
Chester

Christine Foster
Department of Sport and Exercise Sciences
Pavillion 1, Chester Campus
University of Chester

*Centre for Exercise and
Nutrition Science*

*Reader and Research Co-ordinator
Dr Stephen Fallows*

BSc, PhD

Direct Line 01244 513407

Fax 01244 511310

s.fallows@chester.ac.uk

29 March 2007

Dear Christine

Application title: Assessment of small-sided games
SREC reference: 118/07/CF/SES
Version number: 1

Thank you for your letters of March 2007, responding to the School of Health and Applied Sciences Research Ethics Committee's request for further information on the above research and submitting revised documents.

The further information has been considered on behalf of the Committee by the Lead Reviewer (Mohammed Saeed) and the Chair (Stephen Fallows).

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form and supporting documentation as revised.

The favourable opinion is given provided that you comply with the conditions set out in the attached document. You are advised to study the conditions carefully.

The final list of documents reviewed and approved by the Committee is as follows:

Document	Version	Date
SREC Application Form	1	February 2007
Participant Information Sheet	2	March 2007
Consent Form	2	March 2007
Medical Questionnaire	1	February 2007

With the Committee's best wishes for the success of this project.

Yours sincerely,

Dr Stephen Fallows
Chair, School Research Ethics Committee

Enclosures Standard conditions of approval.

c.c.: Supervisor
SREC Representative

Appendix 4B

Study 2 ethical approval



*Centre for Exercise and
Nutrition Science*

Christine Foster
Department of Sport and Exercise Sciences
University of Chester

*Reader and Research Co-ordinator
Dr Stephen Fallows*

BSc, PhD
Direct Line 01244 513407
Fax 01244 511310
s.fallows@chester.ac.uk

07 January 2008

Dear Chrissy

Study title: The physiological and movement demands of attacking and defending within small-sided rugby league games
FREC reference: 191/07/CF/SES
Version number: 2

Thank you for sending the above-named application to the Faculty of Applied and Health Sciences' Research Ethics Committee for review. The application has been considered on behalf of the Committee by Mohammed Saeed as Lead Reviewer and reported to the Faculty's Research Ethics Committee.

On behalf of the Committee, I am pleased to confirm a favourable ethical opinion for the above research on the basis described in the application form and supporting documentation.

This approval is given provided that you comply with the conditions set out in the attached document. You are advised to study the conditions carefully.

The final list of documents reviewed and approved by the Committee is as follows:

Document	Version	Date
Application Form	1	November 2007
Participant Information Sheet	2	December 2007
Participant Consent Form	2	December 2007
Letter of invitation for parents/guardians	1	November 2007
Medical questionnaire	1	November 2007
Laboratory testing protocols	1	December 2007
Field testing protocols	1	December 2007